LONGITUDINAL HEALTH CARE UTILIZATION

BY

ACTIVE DUTY SERVICE MEMBERS

WITH

A FIRST DIAGNOSIS OF MILD TRAUMATIC BRAIN INJURY

by

Lalon M Kasuske

Dissertation submitted to the Faculty of the
Daniel K. Inouye Graduate School of Nursing Philosophical Doctorate Program
Uniformed Services University of the Health Sciences
In partial fulfillment of the requirements for the degree of
Doctor of Philosophy 2017

Board of Regents
Abbreviated Curriculum Vitae

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Distribution Statement

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Attachments:
As stated

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March 30, 2017

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ABSTRACT

Title of Dissertation:

Longitudinal Health Care Utilization by Active Duty Service Members with a First Diagnosis of Mild Traumatic Brain Injury

Lalon M. Kasuske, MBA, RN, 2017

Dissertation directed by:

Penny Pierce, PhD, RN, FAAN, Professor and Director, PhD in Nursing Science Program, Uniformed Services University of the Health Sciences, Daniel K. Inouye Graduation School of Nursing

Background: Mild traumatic brain injury (mTBI) is a frequent cause of injury to active duty service members (SMs). Studies of veterans with mTBI, with or without comorbid psychiatric disorders, reveal increased health care utilization after injury, but few studies exist of health care utilization by active duty SMs following an mTBI. This dissertation is a comprehensive analysis of short-term and long-term health care utilization by a large sample of active duty SMs prior to and following a first diagnosis of mTBI.

Methods: A retrospective analysis of electronic health record data from 46,247 active duty service members with a first diagnosis of mTBI. Health care utilization in the 90 days and 365 days before and after a diagnosis of mTBI were compared using non-parametric statistics. Changes in health care utilization are reported by age, gender, deployment status, and by the presence or absence of PTSD, depression, or substance use disorders.

Results: Median health care utilization for all SMs (n=46,247) doubled in the 90 days following mTBI. Moderate, but statistically significant changes in median utilization were found

among SMs with pre-existing PTSD, who increased from 14 visits pre-injury to 20 visits post-injury ($Z= -23.1$, $p<.001$, $r= -0.45$), pre-existing depression, who increased from 7 visits pre-injury to 11 visits post-injury ($Z=-25.1$, $p<.001$, $r= -0.42$), and pre-existing substance use disorders, who increased from 5 visits pre-injury to 8 visits post-injury ($Z=-30.4$, $p<.001$, $r= -0.38$). Large increases in median utilization were seen by SMs with new onset PTSD, who increased from 3 visits pre-injury to 17 visits post-injury ($Z=-43.6$, $p<.001$, $r= -0.78$), new onset depression, who increased from 3 visits pre-injury to 9 visits post-injury ($Z=-36.0$, $p<.001$, $r= -0.67$), and new onset substance use disorders, who increased from 2 visits pre-injury to 6 visits post-injury ($Z=-47.1$, $p<.001$, $r= -0.87$). Service members with a deployment-related injury increased median utilization from 4 visits pre-injury to 13 visits post-injury ($Z=-73.4$, $p<.001$, $r= -0.67$).

One-year median health care utilization increased for all SMs from 10 visits pre-injury to 20 visits post-injury ($Z=-110.9$, $p<.00$, $r= -0.52$). Service members with a deployment-related injury had the largest increases in one-year utilization, with males increasing median utilization from 9 visits pre-injury to 40 visits post-injury ($Z= -78.3$, $p<.001$, $r= -0.73$) and females increasing from 16 visits pre-injury to 51 visits post injury ($Z=-17.3$, $p<.001$, $r= -0.71$).

Discussion: Outpatient health care utilization increased significantly from pre-injury to post-injury in both the 90-day and 365-day time periods. Males, service members with a war-related injury, and with new onset psychological health conditions demonstrated the largest increases in health care utilization.

Board of Regents
Abbreviated Curriculum Vitae

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Navy and Marine Corps Commendation Medal (2)	U.S. Navy
Navy and Marine Corps Achievement Medal	U.S. Navy

SCHOLARLY PRESENTATIONS

Podium Presentations

Short-term Health Care Utilization by Active Duty Service Members with a first Mild Traumatic Brain Injury
Military Health System Research Symposium, August 2016, Orlando, FL

Electronic Health Records as a Research Lab for Population Health Outcomes – Abstract awarded 2nd place Evidence-Based Practice Award
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The Electronic Health Record as a Research Lab: Leveraging EHR Data to Improve Military Health Outcomes
Summer Institute of Nursing Informatics, University of Maryland, July 2016 Baltimore, MD

Pre-deployment and Post-deployment Health Care Utilization by U.S. Army Soldiers who Screen Positive or Negative for Mild Traumatic Brain Injury
Washington Regional Nursing Research Conference, Catholic University, Dec 2015, Washington, D.C.

Poster Presentations

Analysis of Military Population Health via the Electronic Health Record
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Reliability of Two Portable Heart Rate Measurement Devices
TSNRP Research and Evidence Based Practice Dissemination Course, August 2016, San Antonio, TX

The Usability of Electronic Devices to Collect Nocturnal Heart Failure Information
Uniformed Services University of the Health Sciences, May 14, 2015, Bethesda, MD

UNIFORMED SERVICES UNIVERSITY
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Degree Date: 12 May 2017

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Date passed dissertation proposal oral examination: 31 March 2016

Date passed dissertation oral defense: 29 March 2017

Date dissertation accepted by the GSN: 14 April 2017

I certify that the above named student has fulfilled all requirements for the PhD degree.

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Approval/Disapproval

Director, Doctoral Program: [redacted] **Date:** 14 April 2017
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UNIFORMED SERVICES UNIVERSITY
of the Health Sciences

GSN PhD Program in Nursing Science

Dissertation Defense

Doctor of Philosophy Degree

NAME: LALON KASUSKE

TITLE: Longitudinal Outpatient Health Care Utilization by Active Duty Service Members with a First Diagnosis of Mild Traumatic Brain Injury

Date of Defense: 29 March 2017

The decision of the Dissertation Committee is:

PASS

A. Both the dissertation and the oral defense are satisfactory:_____
B. Minor changes are recommended by the Dissertation Committee that is to be made to the satisfaction of the Dissertation Chairperson:✓

DEFER

A. Major changes in the dissertation are required. Changes must be made to the satisfaction of the Dissertation Chairperson:_____
B. Major changes in the dissertation are required. Changes must be made to the satisfaction of the Dissertation Committee and at that time the oral defense will be rescheduled:_____

FAIL: Neither the oral performance nor the dissertation is adequate:_____

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Director, Doctoral Program:[redacted] Date: 29 March 2017

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Lalon M. Kasuske

March 30, 2017

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Background: Mild traumatic brain injury (mTBI) is a frequent cause of injury of active duty service members (SMs). Studies of veterans, with or without comorbid psychiatric disorders, report increased health care utilization after an mTBI. However, there are few studies of health care utilization by active duty SMs following an mTBI diagnosis. This dissertation is a comprehensive analysis of the change in short- and long-term health care utilization by a large sample of active duty SMs prior to and following a first diagnosis of mTBI recorded in the DoD electronic health record.

Methods: This was a retrospective analysis of electronic health record data from 46,247 active duty service members with a first diagnosis of mTBI. Males comprised 87% of the sample and 26% of SMs had a deployment-related mTBI. Health care utilization 90 days and 365 days prior to and following mTBI diagnosis was analyzed using non-parametric statistics. Changes in health care utilization were compared by age, gender, whether a SM had a deployment-related injury, and by the presence or absence of PTSD, depression, or substance use disorders.

Results: Overall median health care utilization doubled in the 90 days following diagnosis with mTBI. Statistically significant increases in median utilization were found among

SMs with pre-existing PTSD, who increased from 14 visits pre-injury to 20 visits post-injury (Z= -23.1, p<.001, r= -0.45), pre-existing depression, who increased from 7 visits pre-injury to 11 visits post-injury (Z=-25.1, p<.001, r= -0.42), and pre-existing substance use disorders, with an increase from 5 visits pre-injury to 8 visits post-injury (Z=-30.4, p<.001, r= -0.38). Medium to large increases in median utilization were seen by SMs with new onset PTSD who increased from 3 visits pre-injury to 17 visits post-injury (Z=-43.6, p<.001, r= -0.78), new onset depression who increased from 3 visits pre-injury to 9 visits post-injury (Z=-36.0, p<.001, r= -0.67), and new onset substance use disorders who increased from 2 visits pre-injury to 6 visits post-injury (Z=-47.1, p<.001, r= -0.87). Service members with a GWOT-related injury increased median utilization from 4 visits pre-injury to 13 visits post-injury (Z=-73.4, p<.001, r= -0.67).

One-year health care utilization increased moderately (r= -0.52) for all SMs from a median of 10 visits pre-injury to 20 visits post-injury (Z=-110.9, p<.001). Service members with a GWOT-related injury demonstrated the largest increases in utilization, with male GWOT increasing median one-year utilization from 9 visits pre-injury to 40 visits post-injury (Z= -78.3, p<.001, r= -0.73) and female GWOT SMs increasing from 16 visits pre-injury to 51 visits post injury (Z=-17.3, p<.001, r= -0.71).

Discussion: Outpatient health care utilization increased significantly in both the 90-day and 365-day pre-injury to post-injury periods. Males, service members injured while deployed in support of the Global War on Terror, and SMs with new onset psychological health conditions demonstrated the largest increases in health care utilization.

CHAPTER 1

INTRODUCTION

Mild traumatic brain injury, or concussion, is a frequent and prevalent cause of injury in the active duty military. Most service members with a mild traumatic brain injury are expected to recover within days to weeks of injury, but many will report persistent postconcussive symptoms for months or longer afterward, requiring ongoing medical care.

Military service members typically receive health care within the Military Health System while on active duty, but the pattern of health care utilization by active duty service members in the acute post-injury phase following an mTBI has been largely unexplored. Health care utilization by veterans with TBI is far higher than veterans without a TBI, and psychological health comorbidities push health care utilization substantially higher. Despite an existing body of evidence of health care utilization following mTBI in veterans, what is not known is 1) the pattern of health care utilization by active duty service members prior to a first diagnosis of mild traumatic brain injury, 2) the pattern of health care utilization by active duty service members following a first diagnosis of mTBI, and 3) the effect of post-traumatic stress disorder, prior to or following mild traumatic brain injury, on health care utilization by active duty service members.

In this study, the researcher investigated the pre-injury and post-injury patterns of health care utilization by active duty service members with a first diagnosis of mild traumatic brain injury, subsets of whom had post-traumatic stress disorder prior to or following injury, to measure the change in health care utilization and to assess differences in utilization by age, gender, and deployment status at the time of injury.

BACKGROUND

Mild Traumatic Brain Injury in Active Duty Service Members

Traumatic brain injury is an injury to the brain from an external force such as rapid acceleration or deceleration forces, impact from an external object, or penetrating injury (CDC, 2010; Defense and Veterans Brain Injury Center Working Group, 2006). Common causes of mild TBI in service members include sports-related injuries, falls, motor vehicle collisions, and military-related blast events (Center, 2016; Galarneau, Woodruff, Dye, Mohrle, & Wade, 2008). Active duty SMs are most likely to sustain a blast-related mTBI while on deployment, and the conflicts in Iraq and Afghanistan have resulted in frequent exposure to improvised explosive devices, commonly resulting in head and neck injuries, including many traumatic brain injuries (S. o. V. Affairs, 2007; Center, 2016; Owens et al., 2008).

Traumatic brain injury (TBI) has been termed a 'Signature Injury" of the wars in Iraq and Afghanistan, as more than 350,000 service members were diagnosed with a TBI between 2000-2016 (Center, 2016; Tanielian & Jaycox, 2008). Of the known TBIs, approximately 80% are classified as mild TBI (Center, 2016). Mild traumatic brain injury, or concussion, is characterized by the DoD as a TBI occurring with either no loss of consciousness or loss of consciousness for less than 30 minutes, post-traumatic amnesia and alteration of consciousness of less than 24 hours, and an absence of a visible lesion on structural imaging (D. o. V. Affairs & Defense, 2016).

Symptoms following mTBI may include headache, dizziness, fatigue, sleep disturbances, noise and light sensitivity, memory problems, concentration difficulties, irritability, frustration, restlessness, and depression ((Ryan & Warden, 2003; Snell & Halter, 2010). Most civilians identified with mTBI recover within days to several months after injury (G. L. Iverson, 2005;

Kashluba et al., 2004; McLincy, Lovell, Pardini, Collins, & Spore, 2006) however, 5% to 20% of individuals with mTBI report sequelae that persist beyond 3 months (Alves, Macciocchi, & Barth, 1993; G. L. Iverson, 2005; Ruff, 2005). Service members (SMs) returning from Iraq and Afghanistan frequently report mTBI and post concussive symptoms immediately upon return from deployment as well as several months to one year afterward (Hoge et al., 2008; Schneiderman, Braver, & Kang, 2008; Schwab et al., 2017; Stein et al., 2016; Tanielian & Jaycox, 2008; Terrio et al., 2009). The Department of Defense prioritizes early identification of mTBI in service members returning from deployment, with the goal of comprehensive post-deployment screening and early clinical intervention, if needed (S. o. V. Affairs, 2007; Dole & Shalala, 2007).

Health Care Utilization following TBI

Active duty SMs seeking care for mTBI typically do so within the Military Health System (MHS) or through civilian care purchased by the DoD. Understanding how SMs seek health care is vitally important to the readiness of the military, which relies on the active duty population to conduct combat operations, at least in the initial phase of armed conflict. Prolonged combat operations continue to rely upon the active duty military, but may be augmented by reserve or National Guard components. It is important to note that very few studies of health care utilization by active duty SMs currently exist in the literature. What is currently known about health care utilization by military veterans with mTBI comes almost exclusively from analysis of Veterans Health Administration databases.

Studies of health care utilization within the Veterans Health Administration (VHA) have revealed differences in the use of outpatient care, mental health specialty care, and inpatient care related to symptomatology, age, gender, and ethnicity, highlighting the need to better

understand the use of health care services by active duty members (Chatterjee et al., 2009; Duggal et al., 2010; Milliken, Auchterlonie, & Hoge, 2007). Veterans with traumatic brain injury utilize significantly more outpatient services than veterans without TBI, are up to nine times more likely to be hospitalized, and have a higher rate of hospitalizations unrelated to TBI (Drag, Renninger, King, & Hoblyn, 2013). However, outpatient health care utilization is highly associated with the burden of illness in SMs with a diagnosis of TBI (Rogers et al., 2014), as well as SMs who screen positive for TBI versus veterans who screen negative for TBI (S. Maguen, Madden, Lau, & Seal, 2013). Additionally, veterans consistently display sustained higher utilization of health care than veterans without mTBI, suggesting that SMs may continue to utilize health care long after the acute injury has passed (Drag et al., 2013; Taylor et al., 2015).

Many VA studies include only veterans who sought care within the respective study periods, which may explain sustained utilization rates in these studies and reports, as veterans with ongoing health concerns continue to utilize care and those without ongoing concerns significantly decrease or cease utilization. Psychological comorbidity such as post-traumatic stress disorder (PTSD), depression, and substance use disorders likely contribute to the sustained high-rate of healthcare utilization, and mTBI with comorbid PTSD is associated with significantly higher utilization of healthcare than mTBI alone (B. E. Cohen et al., 2010; Drag et al., 2013; Kehle-Forbes, Campbell, Taylor, Scholten, & Sayer, 2016). Comprehensive reports of utilization of VHA care by veterans with mTBI report mean annual outpatient utilization three times higher than veterans without mTBI, including far higher utilization of mental health care (Taylor et al., 2014; Taylor et al., 2015; Taylor et al., 2012). However, when comparing utilization rates to veterans with PTSD and mTBI, TBI+PTSD utilized approximately 150% more

outpatient medical care, and a nearly tenfold rate of mental health care utilization than veterans with mTBI but without PTSD (King, Wade, & Beehler, 2014). Deployment and combat exposure are known to be strongly associated with development of mental health disorders (Hoge, Auchterlonie, & Miliken, 2006; Hoge et al., 2008; Kang, Natelson, Mahan, Lee, & Murphy, 2003), and PTSD and mTBI have been linked to high rates of comorbid conditions such as depression and substance use disorder (SUD) (Carlson et al., 2010; Hoge et al., 2008; Hoge, Terhakopian, Castro, Messer, & Engel, 2007; Schneiderman et al., 2008; Vanderploeg, Belanger, & Curtiss, 2009), highlighting the need to investigate the effect of deployment-related mTBI on health care utilization.

Further, veteran studies have revealed that, in general, females tend to utilize more outpatient services than males, incur slightly higher outpatient costs, and utilize a greater level of pharmacy services (Rogers et al., 2014). As the percentage of active duty forces comprised of women increases, and the operational role of women in the military expands (Congress, 2008a; Congress, 2012a) 46, 47(Center., 2011; O. o. t. D. A. S. o. D. f. M. C. a. F. P. O. M. F. Department of Defense, 2016), there is a need to better understand gender-specific health care needs, particularly among injured SMs. Further, Congress has called for investigation into gender-specific health requirements, particularly investigation of behavioral health services, to anticipate DoD resources to meet future health care needs (Congress, 2008b; Congress, 2012b).

Implications of Mild Traumatic Brain Injury to the Department of Defense

Implications of mTBI to the DoD include financial considerations for the cost of health care, the impact to military operational readiness, and the quality of life of individual SMs. Despite an emphasis on early identification of mTBI and provision of care to injured SMs, the

extent to which mTBI represents an economic, operational or long-term health concern to the MHS is unclear due to a lack of research about the utilization of health care resources by active duty SMs(Dole & Shalala, 2007). There are however, difficulties in estimating the economic impact of TBI, as there are direct care costs, impacts to military readiness, and personal impacts to the individual SM. Rand (Tanielian & Jaycox, 2008) has estimated that average direct care costs in the military range from $618-1487 for one-year outpatient treatment, increasing to $15,144 to $21,346 for patient care of "mild" cases when including estimated inpatient services and pharmacy costs. Economic costs for associated rehabilitation or in those with more severe TBI significantly increase health care costs. When productivity and related costs are considered, deployment related mild TBI is estimated to cost between $25,571 and $30,730 dollars per case, in the first year of clinical care. In a related analysis, the Rand study places the cost of deployment related mental health condition (PTSD and depression) as potentially costing between $120 and $231 million dollars per 50,000 deployed SM, noting further that access to evidence based treatments will reduce costs because of improvements in quality of life, increased productivity and reduced suicide. Median cost of health care utilization beyond the acute phase of injury is sustained as SMs transition to care within the VHA. Annual reports of utilization by veterans with TBI consistently indicate an annual median cost of $5555 for outpatient and pharmaceutical care, approximately four times higher than the annual median cost of a veteran without a history of TBI, and health care costs increased incrementally as comorbidities grew in complexity (Taylor et al., 2014; Taylor et al., 2015). A 2013 study by Stroupe and colleagues found that veterans who screened positive for TBI had total healthcare costs, in the 12 month period following initial evaluation, almost double that of

veterans who screened negative for TBI and nearly three times as much as veterans with no TBI screen (Stroupe et al., 2013). Studies of health care utilization by veterans screened for or diagnosed with mTBI often include only veterans who *received* care in the VHA, and may not accurately reflect the full range of post-injury health care utilization by the population of SMs or veterans with a mTBI, particularly SMs with a low rate of utilization and SMs who did not seek care.

Beyond financial considerations of treating mTBI and related mental health conditions is the impact on military operational readiness. Previous investigations into the impact of mental health conditions found higher rates of attrition from the military by SMs with mental health concerns when compared to attrition by SMs with any non-mental-health medical condition (Garvey Wilson, Messer, & Hoge, 2009; Hoge et al., 2006). Additionally, SMs with mTBI have reported difficulty reintegrating to their military units, due to limitations in performing tasks, a perceived lack of empathy from their fellow SMs, and increased work absences (Hyatt, Davis, & Barroso, 2014).

An additional cost of mTBI is the personal cost of injury. Service members with TBI report higher levels of family stress and marital difficulties (Hyatt et al., 2014; Ponsford & Schonberger, 2010; Vanderploeg, Curtiss, Luis, & Salazar, 2007). Spouses, in bear an additional burden of coping with a brain-injured individual (Gan, Campbell, Gemeinhardt, & McFadden, 2006; Hammond, Davis, Whiteside, Philbrick, & Hirsch, 2011). Multiple deployments to the wars in Iraq and Afghanistan have become commonplace, yet studies of post-deployment screening suggest that service members' reporting of deployment-related mental health symptoms may be delayed by several months (S. Maguen, Madden, Cohen, Bertenthal, & Seal,

2012; Vogt, 2011), suggesting a need to investigate the pattern of health care utilization over a period of months to a year or more in order to identify potential differences in utilization by groups of service members.

Identifying the patterns of health care utilization by active duty SMs prior to and following an mTBI is critically important to the DoD. Given that physical, cognitive, and psychological symptoms related to mTBI affect a significant number of active duty SMs, there is a clear need to better understand the health care requirements of this population in order to accurately forecast true operational readiness of deployable military units, to forecast and appropriately allocate resources for the acute and post-acute health care requirements of the mTBI population, and to identify at-risk SMs who otherwise might not seek health care.

PURPOSE

The purpose of this study is to quantify the pre-injury to post-injury change in health care utilization by active duty SMs with a first diagnosis of mTBI.

OPERATIONAL DEFINITIONS

Health Care Utilization: Use of available health services

Outpatient encounter: A visit to an outpatient clinic within the Military Health System in which any ICD-9-CM code was assigned to the visit. A visit in which multiple ICD-9-CM codes were assigned counts as one visit. A SM could have multiple visits in a single day. Laboratory, radiology, pharmacy consultations, and telephone consultations were not counted as outpatient visits, as they were considered an extension of a visit to another outpatient clinic.

Primary care: Included any outpatient encounter to family practice, internal medicine, medical, medical exam, primary care, pediatric, flight medicine, undersea medicine, or battalion medicine clinics.

Rehabilitation: Included any outpatient encounter to physical therapy, occupational health, orthopedic, physical medicine, pain, chiropractic, orthotics, hand surgery, or rehabilitation ambulatory care clinics.

Mental Health: Included any outpatient encounter to psychology, psychiatry, mental health, child guidance, substance abuse, or social work clinics.

Neurology: Included any outpatient encounter to neurology, neurosurgery, or vestibular audiology clinics.

'All Other' Clinics: Included any outpatient encounter to any clinic not otherwise specified as primary care, rehabilitation, mental health, or neurology.

GWOT / Deployment-related / War-related mTBI: Personal history of mild traumatic brain injury related to the Global War on Terror (GWOT) as indicated by ICD-9-CM code V15.52_2. Although the injury is assumed to have occurred in a forward-deployed setting, the circumstances surrounding injury (blast or combat) are unknown.

Non-GWOT / non-war-related mTBI: Personal history of mild traumatic brain injury documented as being unrelated to the Global War on Terror (GWOT) as indicated by ICD-9-CM code V15.52_7. Although the injury is assumed to have occurred in a garrison or non-deployed setting, the actual cause of injury is unknown.

Pre-existing PTSD: A diagnosis of post-traumatic stress disorder within the 12 months prior to diagnosis with mTBI, as indicated by ICD-9-CM code 309.81.

New Onset PTSD: A diagnosis of post-traumatic stress disorder within the 12 months following a first diagnosis of mTBI, as indicated by ICD-9-CM code 309.81. Excludes SMs with a diagnosis of PTSD in the 12 months prior to mTBI.

RESEARCH QUESTIONS

1) What is pattern of health care utilization by active duty SMs prior to a first diagnosis of mTBI? Health care utilization was measured in the 90 days and 365 days immediately preceding the first diagnosis of mTBI recorded in the military electronic health record (index date).

2) What is pattern of health care utilization by active duty SMs following a first diagnosis of mTBI? Health care utilization was measured in the 90 days and 365 days immediately following the first diagnosis of mTBI recorded in the military electronic health record (index date).

3) How does health care utilization in the pre-injury and post-injury periods differ by age, gender, and deployment status at the time of injury? The pattern of health care utilization, measured by total utilization and utilization of outpatient specialty clinic groups is compared by age groups, gender, and whether a SM had a war-related mTBI.

RESEACH DESIGN

Method

A retrospective analysis of electronic health record data abstracted from the DoD Health Services Data Warehouse (HSDW), including all outpatient encounters by clinic with assigned *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes.

Study Population

The population included all U.S. military personnel who accessed MHS ambulatory care between 2006-2014 and were assigned ICD-9-CM indicating a first diagnosis of mTBI. Service members with ICD-9 codes 850.0 (concussion with no loss of consciousness) and 850.11 (concussion with loss of consciousness of 30 minutes or less) were included in the study, consistent with the VA / DoD definition of mild traumatic brain injury [2]. Service members with less than one year of active duty service prior to or following mTBI were excluded from the study, and only MHS encounters were included in the analysis. As the focus of the study was on full-time active duty SMs with a first diagnosis of mTBI while active duty military, reserve component SMs, non-military members eligible for MHS care, and National Guard SMs were excluded from the study, as were SMs with a diagnosis of moderate or severe TBI. Although the study could not account for pre-military mTBI, SMs with a prior TBI diagnosis recorded in their military health record were excluded, as were SMs with a subsequent TBI within 12 months of the initial mTBI diagnosis.

Data Analysis

Health care utilization was calculated through a count of outpatient visits, irrespective of clinic type, in the 90 day and 365 day time periods preceding and following the initial mTBI

diagnosis. Ninety day windows were chosen, because per DoD Clinical Practice Guidelines, most medical issues resulting from mTBI are expected to resolve within 90 days of injury (D. o. V. Affairs & Defense, 2015b), and 365 day windows were chosen as one-year utilization has frequently been the time period investigated in previous studies, allowing comparisons of utilization over similar time periods. All MHS outpatient clinics were included for analysis of health care utilization, with specific interest in the pattern of utilization of primary care, rehabilitation clinics, mental health services, and neurology clinics. Outpatient care purchased from civilian networks and inpatient care were not included, as utilization of outpatient MHS services was the focus of the study. Total outpatient utilization by the overall sample, as well as utilization by age, gender, and injury status (GWOT or non-GWOT) was compared through non-parametric Wilcoxon Signed Ranks, as the data was not normally distributed, but the difference in median utilization (post-injury minus pre-injury) was symmetrically distributed around the median. The change in median and mean utilization by group, with effect size are reported. Effect sizes (*r)* were calculated from the *z* statistic of the Wilcoxon Signed Rank test as described by Fritz and colleagues (Fritz, Morris, & Richler, 2011), and reported using parameters proposed by Cohen, such as that a large effect is .5, a moderate effect is .3, and a small effect is .1. (J. Cohen, 1988).

Study Sample

The study sample was 46,247 SMs with 292,283 outpatient visits in the 90 days preceding initial mTBI diagnosis, and 679,332 outpatient visits in the 90 days following mTBI diagnosis. The sample was 87% male, and 80% of SMs in the sample were under the age of 35 (n=36,952). Approximately 26% (n=12113) of SMs had a deployment-related mTBI, meaning

the injury was documented by ICD-9-CM code v15.52_2 to have occurred while a SM was deployed in support of the Global War on Terror (GWOT). Although the actual cause of injury is not known to the researchers in this study, blast-related injury is the most common cause of deployment-related mTBI. Eleven percent (11%) of our sample had an mTBI documented to have occurred while the SM was not deployed in support of the GWOT, indicated by ICD-9-CM code V15.52_7. Characteristics of the entire study sample are shown in Table 1 in Appendix A.

A subset of the study sample was used to investigate the effects of post-traumatic stress disorder (PTSD) prior to or following mTBI, on short-term utilization. The sample for this portion of the study was 28,616 SMs, of which 74% (n= 21, 232) had mTBI only, 14.8% (n=4255) had a diagnosis of PTSD prior to mTBI, and 10.9% (n=3129) had a diagnosis of PTSD following mTBI. Demographics for this portion of the study are shown in Table 2, Appendix A.

ASSUMPTIONS

The investigator assumed that service members sought care when symptomatic following mTBI. Additionally, the investigator assumed that SMs were uninhibited from seeking care within the MHS before, during, and after injury.

ORGANIZATION OF THE DOCUMENT

Chapter 2 is a manuscript prepared for submission to a peer-reviewed journal, documenting an investigation of health care utilization by active duty SMs in the 90 days immediately prior to and following a first diagnosis of mTBI in the military EHR.

Chapter 3 is a manuscript prepared for submission to a peer-reviewed journal, documenting an investigation of health care utilization by active duty SMs in the 90 days immediately prior to and following a first diagnosis of mTBI in the military EHR. Subsets of the

SMs had a diagnosis of posttraumatic stress disorder (PTSD) in the year prior to or following diagnosis with mTBI, as well as a subset of SMs without PTSD.

Chapter 4 is a manuscript prepared for submission to a peer-reviewed journal, documenting investigation of health care utilization by active duty SMs in the 365 days immediately prior to and following a first diagnosis of mTBI in the military EHR.

Chapter 5 provides a summation of the findings from the investigations undertaken in chapters two, three, and four. Additionally, the investigator provides recommendations for future studies of health care utilization by active duty SMs.

CHAPTER 2

Short-term Outpatient Health Care Utilization by Active Duty Service Members with a first diagnosis of Mild Traumatic Brain Injury

Abstract

The DoD reports more than 360,000 service members (SMs) experienced a traumatic brain injury (TBI) between 2000-2016, of which 80% were classified as mild. Mild TBI (mTBI) is associated with increased health care utilization by veterans, but is largely unexplored in the active duty military population. We investigated the change in short-term health care utilization following a first diagnosis of mTBI in the military through retrospective analysis of electronic health record data of 46,247 active duty SMs. Outpatient health care encounters in the 90 days prior to and following a first mTBI including primary care and specialty care clinics were compared using Wilcoxon signed rank test, and the results are reported together with the effect size, *r*. Utilization is compared by age, gender, and if SMs were injured while deployed. Among all SMs, median outpatient utilization doubled from 3 visits in the 90 days prior to mTBI to 6 visits in the 90 days following mTBI ($Z=-105$, $p<.001$, $r=.35$). Males had a mean of 6.3($\pm$11.9) visits in the 90 days prior to diagnosis, and 14.7(SD$\pm$26.1) visits in the 90 days post-diagnosis. Females averaged 7.8($\pm$11.4) visits pre-diagnosis and 12.9($\pm$18) visits post-diagnosis. Service members with a war-related injury demonstrated the largest increase in median utilization, increasing from 4 visits pre-injury to 13 visits post-injury ($Z=-73.4$, $p<.001$, $r=.47$). Overall, median utilization of rehabilitation, mental health, and neurology clinics was low pre-injury and post-injury, but overall median utilization increased substantially.

The Department of Defense (DoD) reports more than 360,000 traumatic brain injuries to service members (SMs) between 2000-2016, of which approximately 80% are classified as mild (Center, 2016). Mild traumatic brain injury (mTBI) is characterized by the DoD as a TBI occurring with either no loss of consciousness or loss of consciousness for less than 30 minutes, post-traumatic amnesia and alteration of consciousness of less than 24 hours, and an absence of a visible lesion on structural imaging (D. o. V. Affairs & Defense, 2015a). Following mTBI, patients may experience physical, psychological, and cognitive deficits lasting a period of hours or days or longer. Although most people recover within days to weeks of injury (Bolzenius, Roskos,

Salminen, Paul, & Bucholz, 2015; Schneiderman et al., 2008; Terrio et al., 2009; Vanderploeg et al., 2014), some report persistent symptoms. These symptoms can be exacerbated by multiple factors including characteristics of the injury itself, premorbid characteristics of the person themselves, and co-morbid health conditions including pain, mood changes, stress symptoms and injuries to other parts of the body (Belanger, Kretzmer, Vanderploeg, & French, 2010; Brickell; French, 2010; French et al., 2014; Lange, Brickell, French, et al., 2013; Lange, Brickell, Ivins, Vanderploeg, & French, 2013).

Active duty SMs seeking care for mTBI typically do so within the Military Health System (MHS) or through civilian care purchased by the DoD. Despite an emphasis on early identification of mTBI and provision of care to injured SMs, the extent to which mTBI represents long-term health, and economic, concern to the MHS is unclear due to a lack of evidence about the utilization of health care resources by active duty SMs with mTBI (Dole & Shalala, 2007).

Understanding how active duty SMs seek health care is vitally important to the readiness of the military, which relies most heavily on the active duty population to conduct combat operations in the initial phase of armed conflict. Prolonged combat operations continue to rely upon the active duty military, but may be augmented by reserve or national guard components. Delay in reporting of symptoms, or receipt of health care, by active duty SMs may lead to inaccurate estimates of operational readiness, and SM have reported difficulty reintegrating to individual units following mTBI (Hyatt et al., 2014). Additionally, SMs with mTBI report lower quality of life and increased marital stress compared to SMs without mTBI (Hyatt et al., 2014). Given that physical, cognitive, and psychological symptoms related to mTBI affect a significant number of active duty SMs, there is a clear need to better understand the health

care requirements of this population to accurately estimate operational readiness of deployable military units.

Health care utilization is defined as use of available health care resources, and may provide insight into patterns of care by individuals prior to and following injury, long-term outcomes, and the natural history of an injury. Identifying characteristics of SMs with high levels of health care utilization is an important aspect of MHS resource allocation and may inform future research examining injury-related health care needs for active duty SMs. Studies of veterans with mTBI have revealed differences in utilization of Veterans Health Administration (VHA) outpatient primary care, mental health specialty care, and inpatient care related to symptomatology, age, gender, ethnicity, and type of military service (Chatterjee et al., 2009; Duggal et al., 2010; Milliken et al., 2007; Rogers et al., 2014) However, few studies of health care utilization by active duty SMs following mTBI currently exist, and VHA care typically occurs months to years following initial mTBI, therefore not capturing changes in health care utilization in the acute injury period. Additionally, a review of the literature did not identify pre-injury benchmarks of utilization by veterans or SMs. In order to document increased post-injury health care utilization, it is necessary to have a preinjury utilization rate.

Given the lack of evidence of health care utilization in the acute phase of mTBI, the lack of evidence of pre-injury health care utilization, and limited evidence of post-mTBI health care utilization by active duty SMs, the purpose of this study is to capture the pre-injury to post-injury change in short-term health care utilization by active duty SMs with a first diagnosis of mTBI. The research questions we investigated were, 1) what is pattern of health care utilization in the 90 days prior to injury in active duty SMs with a first diagnosis of mTBI in the military, 2)

what is the pattern of health care utilization in 90 days following injury by active duty SMs with a first diagnosis of mTBI in the military, and 3) how does health care utilization differ pre and post-injury by age, gender, and deployment status at the time of injury?

METHOD

A retrospective analysis of electronic health record data abstracted from the DoD Health Services Data Warehouse (HSDW). The dataset included all outpatient encounters between 2006-2014 by active duty SMs with a diagnosis of TBI indicated by *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes. The dataset included only SMs with at least one year of health record data prior to and following the index date of diagnosis with mTBI. Service members with ICD-9 codes 850.0 (concussion with no loss of consciousness) and 850.11 (concussion with loss of consciousness for less than 30 minutes) were included in the study, consistent with the VA / DoD definition of mild traumatic brain injury [2]. As the focus of the study was on full-time active duty SMs with a first diagnosis of mTBI while active duty military, reserve component SMs, non-military members eligible for MHS care, and National Guard SMs were excluded from the study, as were SMs with a diagnosis of moderate or severe TBI, and only MHS encounters were included in the analysis Although the study could not account for pre-military mTBI, SMs with a prior mTBI diagnosis recorded in their military health record were excluded, as were SMs with a subsequent TBI within 12 months of the initial mTBI diagnosis.

Data Analysis

The short-term health care utilization was calculated through a count of outpatient visits, irrespective of clinic type, in the 90 days preceding and 90 days following diagnosis of

mTBI. Ninety day windows were chosen, because per DoD Clinical Practice Guidelines, most medical issues resulting from mTBI are expected to resolve within 90 days of injury (D. o. V. Affairs & Defense, 2015a). All MHS outpatient clinics were included for analysis of health care utilization, with specific interest in the pattern of utilization of primary care, rehabilitation clinics, mental health services, and neurology clinics. Outpatient care purchased from civilian networks and inpatient care were not included, as utilization of outpatient MHS services was the focus of the study. Total outpatient utilization by the overall sample, as well as utilization by age, gender, and deployment status (GWOT or non-GWOT) was compared through non-parametric Wilcoxon signed rank test, as the data was not normally distributed, but the distribution of the differences between pre and post injury was symmetrical. Median and mean utilization by group is reported. Effect size (*r)* was calculated from the *Z* statistic of the Wilcoxon signed rank test as described by Fritz and colleagues (Fritz et al., 2011), and reported using parameters proposed by Cohen, such that .5 is a large effect, .3 is a medium effect, and .1 is a small effect. (J. Cohen, 1988).

Study Sample

The final sample was 46,247 SMs with 292,283 outpatient visits in the 90 days preceding initial mTBI diagnosis, and 679,332 outpatient visits in the 90 days following mTBI diagnosis. The sample was 87% male, and 80% of SMs in the sample were under the age of 35 (n=36,952). Approximately 26% (n=12113) of SMs had a deployment-related mTBI indicated by ICD-9-CM code v15.52_2 (mild TBI, injury related to Global War on Terrorism (GWOT)). Although the actual cause of injury is not known to the researchers in this study, blast-related injury is the most common cause of deployment-related mTBI. Eleven percent (11%) of our sample had an

mTBI documented to have occurred while the SM was not deployed in support of the GWOT, indicated by ICD-9-CM code V15.52_7 (mild TBI, injury not related to Global War on Terrorism (non-GWOT), and 63% of our sample did not a deployment status documented in the electronic health record. Characteristics of our study sample are shown in Table 1.

RESULTS

Results include mean (SD) and median utilization. For cumulative utilization as well as utilization by each outpatient clinic category, mean utilization estimates were larger than median estimates, suggesting that the mean utilization values for this cohort of SMs were influenced by a small number of subjects with high utilization rates. Median utilization, therefore, may offer a more accurate view of the typical utilization by an individual SM in the pre-injury and post-injury timeframes, but mean utilization offers insight into the wide range of utilization by SMs. Mean and median utilization are shown in Table 2.

Pattern of Health Care Utilization

In the 90 days prior to mTBI, 78% of males and 88% of females had one or more outpatient visits. Mean utilization in the 90 days prior to the mTBI index date was 6.3($\pm$11.9) visits, and 14.7($\pm$26.1) in the 90 days post-diagnosis. Median utilization doubled from three to six visits ($Z=-105$, $p<.001$, $r=.35$), with 92% of SMs having at least one visit. Males averaged 6.1($\pm$12) visits pre-injury, and 14.94($\pm$27) visits post-injury. Post-injury median utilization by males was larger than pre-injury utilization, with median utilization increasing from three visits to six visits ($Z=-101.5$, $p<.001$, $r=.36$). Females averaged 7.8($\pm$11.4) visits pre-injury and 12.9($\pm$18) visits post-injury. Post-injury median utilization by females increased from four visits

to seven visits (Z=30.2, p<.001, r=.28). Pre-injury and post-injury mean utilization is shown in Figure 1.

Service members with a war-related mTBI (GWOT) had the largest increase in utilization from a median of 3 visits pre-injury to 13 visits post-injury ((Z=-73.4, p<.001, r=.67). Mean utilization pre-injury was 8.43(±26.4) visits, and 26.4(±37.7) visits post-injury. Approximately 79% of GWOT SMs had at least one outpatient visit prior to injury, compared to 97% post-injury.

Median utilization of outpatient clinics was low pre-and post-injury, with most SMs seeking care within primary care. Approximately 84% of females saw primary care (mean of 4 visits), compared to 75% of males with an average of 3 visits. Post-injury, 34% of SMs had at least one rehabilitation encounter, 38% saw mental health, and 20% of SMs were seen in neurology. Of war-injured SMs, 50% had at least one mental health visit (mean 5.8±12), 45% had a rehabilitation encounter (mean 6.7±16.5), and 43% were seen in neurology (mean 1.9±7.4) clinics. Pre-injury and post-injury utilization by clinic is shown in Table 3 and Figure 2.

DISCUSSION

This study examined patterns of outpatient health care utilization in a large sample of active duty service members prior to and following a first diagnosis of mTBI. Mean utilization increased significantly form pre-injury to post-injury in terms of overall utilization as well as utilization of outpatient specialty clinics, but median utilization was very low both pre-injury and post-injury.

Service members are generally healthy, and generally utilized low levels of care in the three months prior to injury. Despite low median utilization prior to and following injury, service members take advantage of access to care, as 80% of SMs had one or more visits in the pre-injury period, and 91% had at least one visit in the post-injury period. Approximately 25% of SMs sought care in mental health outpatient clinics prior to injury, and 38% of SMs sought care in mental health clinics post-injury. Despite previous studies reporting hesitation by active duty SMs at seeking mental health treatment due to perceived stigmatization (Bagalman, 2013; Hoge et al., 2006; Hoge et al., 2004; Pietrzak, Johnson, Goldstein, Malley, & Southwick, 2009), the high rate of pre-injury utilization of mental health care may represent a change in the mindset of SMs in seeking help for psychiatric problems, as has been reported in a previous study (Quartana et al., 2014). Although we did not evaluate deployment rates or cumulative deployment time as a part of this study, deployment and combat have been shown to be strongly associated with mental health disorders (Hoge et al., 2006; Hoge et al., 2008; Kang et al., 2003) , and it is likely that a significant percentage of our study population had completed one or more military deployments in support of the wars in Iraq and Afghanistan, as the study period included several of the peak war years. The DoD has mandated pre-deployment and post-deployment screening for SMs, including screening for mental health symptoms, which likely contributes to pre-injury and post-injury utilization of mental health clinics. A 2009 study by Garvey-Wilson and colleagues found that approximately 12% of active duty SMs had a mental health diagnosis prior to wars, and a 2006 study by Hoge and colleagues found that 35% of Iraq war veterans accessed mental health services in year after returning from deployment (Hoge et al., 2006). However, median utilization of mental health services was zero visits post-

injury in our sample, which may indicate that SMs seek mental health care only when referred by primary care, that a percentage are receiving mental health care within primary care clinics, or that SMs are not consistently seeking mental health care. Given the short-term window of post-injury utilization examined by this study, it may be that SMs have not had adequate time to engage in mental health services, suggesting a need for a longer window of post-injury observation.

Important differences in utilization between males and females were found, as well. Pre-injury, females SMs had slightly higher mean and median utilization than males. Following injury, females continued to have a slightly higher median utilization, but male SMs had a large increase in utilization compared to a medium increase by females, in terms of magnitude as measure by effect size. Previous studies of VA utilization, have reported higher utilization of outpatient clinics by females over one-year periods of observation(Drag et al., 2013; Rogers et al., 2014) Women had higher mean and median utilization of primary care pre-and post-injury, but pre-injury gender differences in utilization of outpatient specialty clinics were minimal. Post injury, males had higher mean utilization of mental health, rehabilitation, and neurology clinics than females, with no gender difference in median utilization. This is indicative of a subset of males who are high utilizers of care. A likely explanation of this difference is the number of male SMs who engaged in direct combat, which women were largely excluded from due to DoD regulations excluding women from most non-aviation direct combat roles prior to 2013. As the proportion of active duty females engaged in direct combat continues to grow, additional investigation of gender differences in war-related patterns of health seeking

behavior should be undertaken to understand potential gender-related differences in war-related injuries and post-injury recovery.

Not unexpectedly, SMs with war-related traumatic brain injury utilized the highest levels of total outpatient care, and utilized significantly high levels of specialty care. At least a portion of this utilization may be attributable to serving in a war zone, and confirms an increased risk of mental health disorders following deployment has been reported previously (Milliken et al., 2007; Seal, Bertenthal, Miner, Sen, & Marmar, 2007). As expected, war-injured SMs have the largest increase in mental health utilization and neurology clinics, which may support previous studies attributing persistent mTBI symptomatology to psychological factors, at least for SMs injured during a combat deployment (Fear et al., 2009; Hoge et al., 2008; Killgore, Stetz, Castro, & Hoge, 2006; Wilk, Herrell, Wynn, Riviere, & Hoge, 2012). Although reasons for utilization was not investigated in this study, the large increase in utilization in mental health and neurology clinics by war-injured versus non-war-injured veterans highlights a need for future investigation into long-term post-mTBI utilization patterns by active duty SMs, to investigate if these increases are sustained, and if there are differences in long-term recovery related to patterns of health care utilization.

Limitations

Several limitations of this study are considered. First, substantial limitations exist in using electronic health record data as an indication of mTBI status. Previous work has found ICD-9 coding to both under-estimate and over-estimate mTBI (Bazarian, Veazie, Mookerjee, & Lerner, 2006; Moss & Wade, 1996; Powell, Ferraro, Dikmen, Temkin, & Bell, 2008). One study found that almost half of all inpatients admitted with a head injury did not have an mTBI ICD-9

code documented, likely due to clinical focus on other bodily trauma (Moss & Wade, 1996). Another study found that, of patients assigned an mTBI diagnostic code during an emergency department encounter, only 46% had an mTBI on clinical interview (Bazarian et al., 2006). Finally, mTBI is estimated to be vastly under-reported in civilians, and this is likely the case in active duty SMs as well. Despite the presence of a diagnostic code and standardized provider training across the MHS, there is no efficient means to verify the true presence of traumatic brain injury, its severity or the events surrounding injury, which may be particularly salient in the cases of war-related mTBI. Approximately 63% of our sample did not have a deployment status documented in their record, which is a significant limitation, as the mean and median utilization of SMs with a documented deployment status was higher than SMs whose status is 'unknown,' which may represent an artificially high rate of utilization within these groups.

Additionally, this study does not attempt to account for comorbid conditions such as PTSD depression, or substance use disorder which are known to commonly be associated with increased health care utilization (Kehle-Forbes et al., 2016; Miles, Graham, & Teng, 2014; Stein et al., 2016). As the focus of this study was on mTBI, irrespective of premorbid or comorbid status, we did not account for psychiatric conditions that may have existed prior to or following mTBI. The presence or absence of psychiatric conditions prior to and following an mTBI can be derived from ICD-9 codes, and future studies of the relationship between premorbid and comorbid conditions and health care utilization by the active duty population are needed. Finally, it should be noted that the Department of Defense mandates medical assessment following a TBI in some cases, regardless of the presence of symptoms, and in 2012, issued an instruction for mandated screening after potential TBI causing events in a deployed

environment (Defense., 2012). Additionally, the DoD also mandates screening visits prior to and following deployment, which likely accounts for some visits, although the actual quantity could not be derived from our data, as many deployment screening visits take place within primary care clinics [46]. Included in these directives, if three or more concussions have been documented within a 12 month period the SM must undergo a comprehensive neurologic/cognitive evaluation prior to return to duty (Helmick et al., 2015). Overall, the DoD has instituted a care system for TBI that provides ready access to services that might be needed.

Conclusions

The purpose of this study was to investigate short-term outpatient health care utilization in the population of active duty SMs diagnosed with a first mTBI in the military. This study provides important evidence of the acute post-injury health care utilization by SMs diagnosed with a first mTBI, an important consideration in the treatment of an injury that is frequent and prevalent in deployed SMs as well as those in garrison. Although mean and median utilization doubled in the 90 days following a first diagnosis of mTBI, overall median utilization was very low for most SMs. War-injured SMs had the largest increase in overall utilization as well as utilization of rehabilitation, mental health, and neurology clinics, highlighting a need for long term study of this population to determine if increases in utilization are sustained. Evidence of high utilization by a subset of SMs is indicated, requiring further investigation of differences in this population, to better understand the impacts on MHS resources, impacts on military operational readiness, and the impact to the personal lives of these service members.

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Table 1: Characteristics of active duty SMs with a first diagnosis of mTBI in the military

	Male		Female		Total	
	n	%	n	%	n	%
	40404	87%	5843	13%	46247	
Age						
17-24	15898	39%	2623	45%	18521	40%
25-34	16263	40%	2168	37%	18431	40%
35-44	6626	16%	788	13%	7414	16%
45-Over	1617	4%	264	5%	1881	4%
Service						
USA	24844	61%	2920	50%	27764	60%
USAF	5379	13%	1503	26%	6882	15%
USN	4338	11%	1016	17%	5354	12%
USMC	5843	14%	404	7%	6247	14%
Deployment Status						
GWOT	11524	29%	589	10%	12113	26%
Non-GWOT	4156	10%	713	12%	4869	11%
Unknown	24724	61%	4541	78%	29265	63%

GWOT: Global War on Terrorism, representing SMs with a deployment-related

Non-GWOT: SMs with mTBI documented as unrelated to the Global War on Terrorism, as indicated by ICD-9-CM code V15.52_7

Table 2: 90 day pre-injury and 90 day post-injury median utilization with effect size

		Pre		Post			
	N	Median	Mean	Median	Mean	Z	Effect Size
Overall	46247	3	6.3	6	14.69	-105.488	0.35
17-24	18521	2	5	5	13.14	-65.801	0.34
25-34	18431	3	6.5	6	15.03	-68.097	0.35
35-44	7414	4	8.3	8	16.51	-41.655	0.34
45-Over	1881	5	10.3	11	19.45	-21.252	0.35
Male	40404	3	6.1	6	14.94	-101.336	0.36
Female	5843	4	7.8	7	12.93	-30.187	0.28
non-GWOT	4869	3	6.6	9	18.13	-44.468	0.45
GWOT	12113	4	8.4	13	26.37	-73.426	0.47
Unknown	29265	2	5.4	4	9.3	-61.275	0.25

Results obtained using non-parametric Wilcoxon Signed Ranks with statistical significance of $p<.001$. Effect sizes caluclated from the Z statistic.

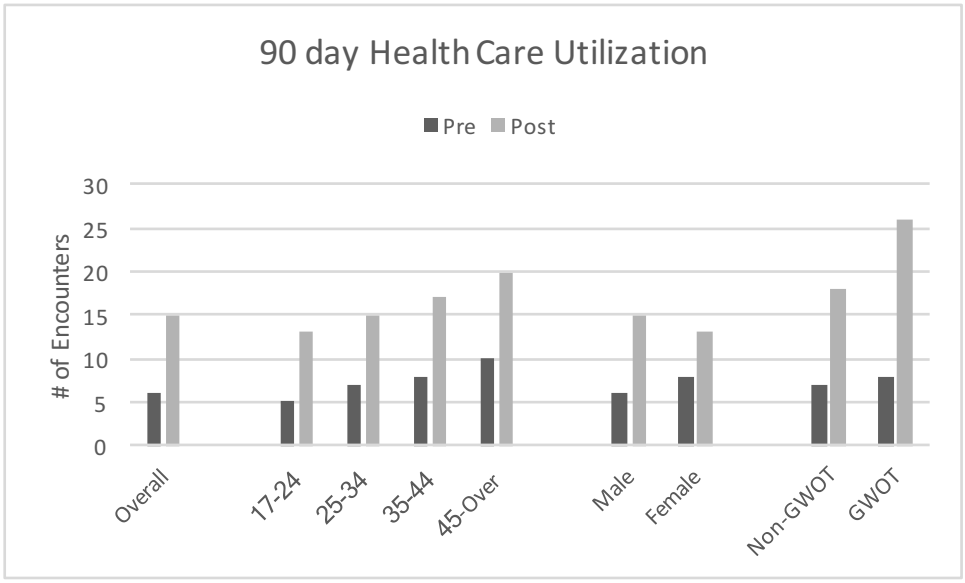

Figure 1: 90 day pre-injury and post-injury mean health care utilization. Figures for mean utilization are reported in Table 2.

Table 3: 90 day pre-injury to 90 day post-injury mean and median utilization by outpatient clinic groups

	Primary Care				Rehabilitative				Mental Health				Neurology				All Other			
	Pre		Post		Pre		Post		Pre		Post		Pre		Post		Pre		Post	
	Mean (SD)	(25-75th Percentile)	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti	Mean (SD)	(25-75th Percenti
Sample	1.9 (2.8)	1 (0-3)	3.2 (4.2)	2 (1-4)	1.1 (4.3)	0 (0-0)	(10.9)	2 (1-4)	1.4 (5.4)	0 (0-0)	3.0 (8.8)	0 (0-2)	(.64)	0 (0-0)	.85 (4.3)	0 (0-0)	1.6 (4.6)	0 (0-1)	(10.2)	1 (0-3)
17-24	1.6 (3.7)	1 (0-2)	1.9 (2.7)	2 (0-4)	.78 (3.7)	0 (0-0)	1.1 (4.3)	0 (0-0)	.99 (4.5)	0 (0-0)	1.6 (5.7)	0 (0-1)	.11 (.57)	0 (0-0)	.13 (.63)	0 (0-0)	1.3 (4.7)	1 (0-3)	(10.6)	1 (0-3)
25-34	1.9 (2.7)	1 (0-3)	3.3 (4.3)	2 (1-4)	1.1 (4.3)	0 (0-0)	(10.7)	0 (0-2)	1.6 (5.7)	0 (0-1)	1.9 (6.8)	0 (0-1)	.13 (.63)	0 (0-0)	.84 (3.9)	0 (0-0)	1.6 (4.6)	0 (0-1)	4 (10.2)	1 (0-3)
35-44	2.5 (3.3)	2 (0-3)	3.8 (4.6)	2 (0-3)	1.6 (4.9)	0 (0-1)	3.6 (8.6)	0 (0-3)	1.9 (6.8)	0 (0-1)	3.7 (9.7)	0 (0-4)	.16 (.78)	0 (0-0)	1.2 (6.5)	0 (0-0)	2 (4.9)	0 (0-2)	4.1 (9.1)	1 (0-4)
45-Over	3.1 (3.8)	2 (0-4)	4.2 (4.9)	3 (1-6)	2.1 (5.2)	0 (0-2)	4.4 (8.5)	0 (0-5)	1.7 (4.9)	0 (0-1)	3.9 (9.6)	0 (0-4)	.21 (.77)	0 (0-0)	1.3 (7.1)	0 (0-1)	3 (5.9)	1 (0-3)	5.6 (9.9)	2 (0-6)
Male	1.8 (2.7)	1 (0-2)	3.1 (4.2)	2 (1-4)	1.1 (4.3)	0 (0-0)	(11.3)	0 (0-2)	1.4 (5.4)	0 (0-0)	3.1 (8.9)	0 (0-2)	.13 (.64)	0 (0-0)	.9 (4.6)	0 (0-0)	1.6 (4.6)	0 (0-1)	(10.6)	1 (0-3)
Female	2.8 (3.1)	2 (1-4)	3.9 (4.1)	3 (1-5)	1.2 (3.8)	0 (0-0)	2.5 (7.1)	0 (0-2)	1.5 (5.6)	0 (0-0)	2.5 (7.4)	0 (0-2)	.11 (.64)	0 (0-0)	.5 (1.9)	0 (0-0)	1.9 (4.2)	1 (0-2)	3.2 (6.7)	1 (0-3)
GWOT	2 (3.1)	1 (0-3)	4.5 (5.6)	3 (0-6)	1.6 (5.8)	0 (0-1)	(16.5)	1 (0-6)	2.2 (6.9)	0 (0-1)	5.8 (12)	2 (0-7)	.25 (.8)	0 (0-0)	1.9 (7.4)	0 (0-1)	2.2 (6)	0 (0-2)	(14.7)	2 (0-7)
GWOT	1.9 (2.8)	1 (0-3)	3.6 (4.4)	2 (1-5)	1.2 (4.2)	0 (0-0)	(10.5)	0 (0-4)	1.3 (5.4)	0 (0-0)	3.2 (9.3)	0 (0-3)	.1 (.6)	0 (0-0)	1.5 (3.8)	0 (0-2)	1.8 (4.6)	0 (0-2)	(10.6)	1 (0-5)
Unknown	1.8 (2.6)	1 (0-3)	2.7 (3.3)	2 (0-4)	.84 (3.4)	0 (0-0)	1.8 (7)	0 (0-1)	1.1 (4.7)	0 (0-0)	1.8 (6.5)	0 (0-1)	.08 (3.4)	0 (0-0)	.29 (1.9)	0 (0-0)	1.4 (3.8)	0 (0-1)	2.5 (7)	1 (0-2)

All results obtained using non-parametric Wilcoxon Signed Ranks with statistical significance of p<.001.

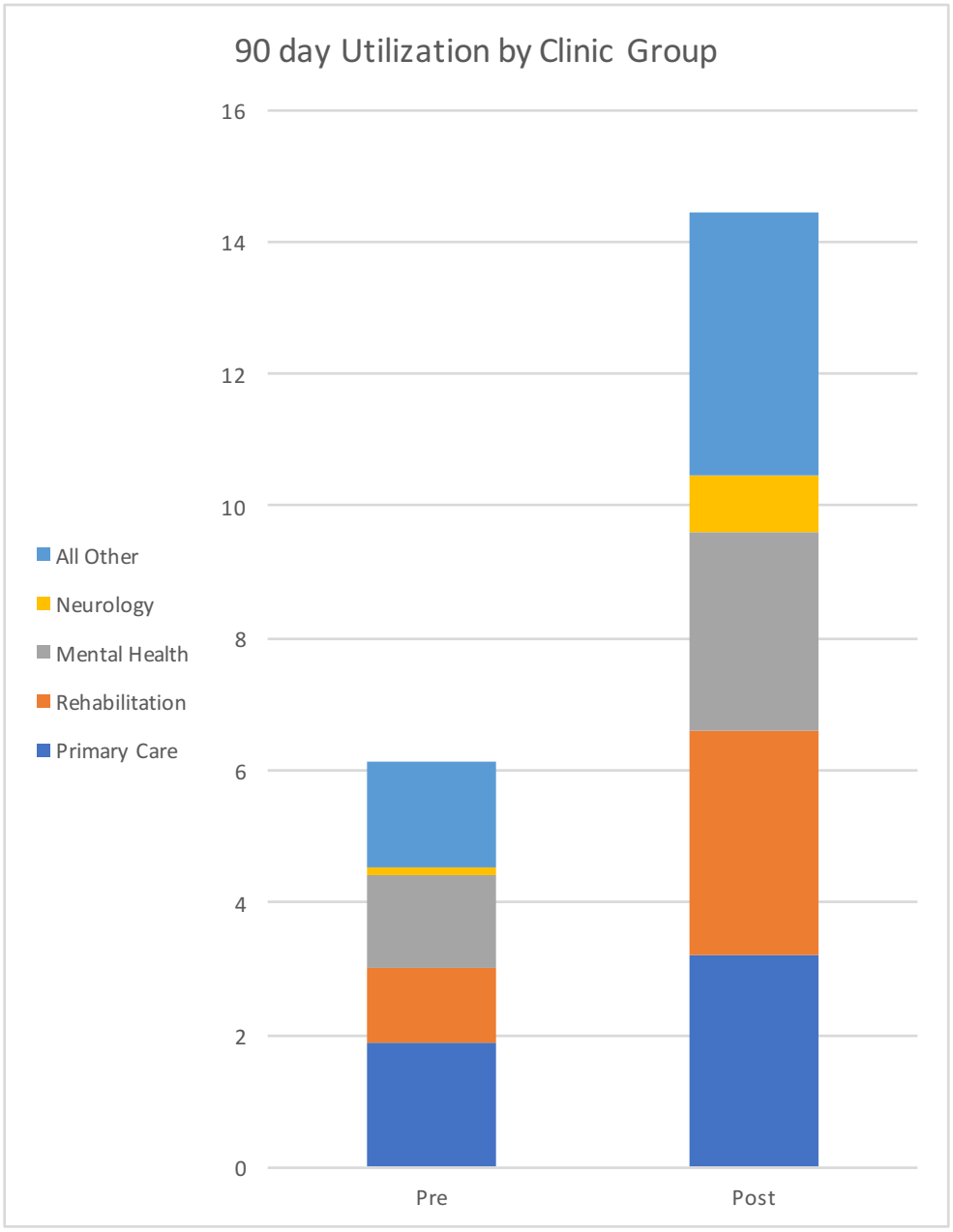

Figure 2. Overall (n=46,247) mean short-term utilization by outpatient clinic group, pre-injury and post-injury, by SMs with a first diagnosis of mTBI in the military. Utilization by clinic group is reported in Table 3.

CHAPTER 3

Short-term Health Care Utilization by Active Duty Service Members with Mild TBI: Effect of Pre-existing and New Onset PTSD

Abstract
Posttraumatic stress disorder (PTSD) and mild traumatic brain injury (mTBI) share several symptoms, and each has been linked to high rates of health care utilization by active duty service members (SMs) and veterans, but little evidence of the effect of pre-exiting versus new onset PTSD on health care utilization has been reported in the literature. We investigated short-term healthcare utilization through retrospective analysis of electronic health records of 28,616 of active duty SMs with a first diagnosis of mTBI in the military, subsets of whom were diagnosed with PTSD prior to or following mTBI. Rates of premorbid and comorbid PTSD, as well as mTBI_Only were calculated using ICD-9 codes. Outpatient health care encounters in the 90 days prior to and following mTBI were analyzed using Wilcoxon signed rank test, and the results are reported by using the value of the test statistic, p-value, and effect size, *r*. We found that 74% (n=21,232) of SMs had mTBI only, 15% (n=4255) had a diagnosis of PTSD prior to mTBI, and 11% (n=3129) had a diagnosis of PTSD following mTBI. Service members with mTBI_Only or new onset PTSD averaged 3.2($\pm$6) visits prior to injury, compared to an average of 20.4($\pm$21.7) visits by SMs with pre-existing PTSD. Pre-injury to post-injury, SMs with mTBI_Only increased median utilization from 2 visits to 4 visits ($Z=-65.05$, $p<.001$, $r=.32$), SMs with pre-existing PTSD increased from 14 visits to 20 visits ($Z=-23.08$, $p<.001$, $r=.25$), and SMs with new onset PTSD increased from 3 visits to 17 visits ($Z=-43.01$, $p<.001$, $r=.55$). The highest utilization was demonstrated by SMs with a war-related injury and new onset PTSD, who demonstrated a large increase, from a pre-injury median of 3 visits to a post-injury median of 23 visits ($Z=-35.09$, $p<.001$, $r=.58$). Mean utilization by GWOT SMs was 5.6($\pm$12.3) visits pre-injury and 39($\pm$46.2) post-injury. In general, utilization increased with increasing age, males utilized less mean care than females prior to injury and males utilized more care than females following injury. Service members younger than 35 who had new onset PTSD had higher utilization than older SMs, and SMs with a deployment-related injury utilized the highest levels of care.

The Department of Defense (DoD) reports more than 360,000 traumatic brain injuries to service members (SMs) between 2000-2016, of which approximately 80% are classified as mild (Center, 2016). Mild traumatic brain injury, or concussion, is characterized as a TBI occurring with either no loss of consciousness or loss of consciousness for less than 30 minutes, post-traumatic amnesia and alteration of consciousness of less than 24 hours, and an absence of a visible lesion on structural imaging (D. o. V. Affairs & Defense, 2016). Common causes of TBI in

service members include sports-related injuries, falls, motor vehicle collisions, and military-related blast events (Center, 2016; Galarneau et al., 2008). Early identification of mTBI in service members returning from deployment is a priority of the DoD comprehensive post-deployment screening (Dole & Shalala, 2007) (S. o. V. Affairs, 2007). Service members returning from Iraq and Afghanistan frequently report mild traumatic brain injury and postconcussive symptoms immediately upon return from deployment as well as several months to one year afterward (Hoge et al., 2008; Schneiderman et al., 2008; Stein et al., 2016; Tanielian & Jaycox, 2008; Terrio et al., 2009). PTSD and mTBI share several symptoms including sleep disturbances, difficulty with recall, impulsivity, mood disturbances, and anxiety disorders (Cooper et al., 2011; Pietrzak et al., 2009; Polusny et al., 2011).

Mild traumatic brain injury is associated with increased utilization of outpatient health care in veteran populations, and mTBI with comorbid PTSD is associated with significantly higher utilization of healthcare than mTBI alone (B. E. Cohen et al., 2010; Drag et al., 2013; Kehle-Forbes et al., 2016). Comprehensive reports of utilization of VHA care by veterans with mTBI report mean annual outpatient utilization of 29.4-34.9 total visits, versus 10.7-12.3 annual outpatient visits for veterans without mTBI, including far higher utilization of mental health care (Taylor et al., 2014; Taylor et al., 2015; Taylor et al., 2012). However, subsets of veterans with PTSD and mTBI have been reported to utilize approximately 150% more outpatient medical care, and a nearly tenfold rate of mental health care utilization than veterans with mTBI without PTSD (King et al., 2014).

Active duty service members requiring medical care typically are treated within the Military Health System (MHS), which provides comprehensive inpatient, outpatient, and

pharmacy services. A primary mission of the MHS is ensuring active duty SMs are medically ready for operational deployment, thereby treating SMs who are acutely ill or injured, including SMs with mTBI. Despite ample evidence of increased health care utilization by TBI+ veterans utilizing care with the Veterans Health Administration, few studies of health care utilization by active duty SMs with mTBI and related comorbidities exist. Veteran studies are unlikely to capture short-term implications of concussion as veterans seeking care within the VHA typically do so months-to-years post-injury. Investigating the acute phase of injury is critically important to military operational readiness and resource allocation within the Military Health System. Therefore, the specific aim of this study is to quantify short-term health care utilization by active duty SMs with a first diagnosis of mTBI, including SM with premorbid or comorbid PTSD. The research questions we investigated were: 1) what is the pattern of health care utilization prior to and following a first mTBI by active duty service members with PTSD prior to diagnosis with mTBI, 2) what is the pattern of health care utilization prior to and following a first mTBI by active duty service members with a diagnosis of PTSD following diagnosis with mTBI, and 3) what is the pattern of health care utilization prior to and following a first mTBI by active duty service members without PTSD?

METHOD

A retrospective analysis of electronic health records of active duty SMs with a first diagnosis of mTBI in the military. Data for this analysis were abstracted from the Department of Defense (DoD) Health Services Data Warehouse (HSDW) and included all outpatient health care encounters by clinic, associated *International Classification of Diseases, 9th Revision,*

*Clinical Modification (*ICD-9-CM) diagnostic codes, and SM demographic information. The dataset included only SMs with at least one year of health record data prior to and following the index date of mTBI diagnosis.

Study Population

All U.S. military personnel who accessed ambulatory care within the Military Health System between 2006-2014 and were assigned an ICD-9-CM code indicating a first diagnosis of mTBI were included in the study population (n=83,878). Mild TBI was limited to ICD-9-CM codes 850.0 (concussion with no loss of consciousness) and 850.11 (concussion with loss of consciousness of 30 minutes or less), consistent with the VA / DoD definition of mTBI. The dataset included only MHS outpatient encounters, and only full-time active duty military SMs were included in the final study sample. Service members with a history of previous mild, moderate, or severe TBI were excluded from the study, as were SMs with a subsequent TBI within 12 months of the initial mTBI diagnosis.

Service members designated 'mTBI_Only' had no diagnosis of PTSD, depression, or a substance abuse disorder, excluding nicotine abuse, in the 12 months prior or 12 months following diagnosis with mTBI. Pre-existing PTSD (PTSD_Pre) cases were developed from SMs with a diagnosis of PTSD in the 12 months immediately prior to a first mTBI, as indicated by ICD-9-CM code 309.81, documented in the EHR. New onset PTSD (PTSD_New) cases were developed from SMs who had no diagnosis of PTSD in the 12 months immediately prior to mTBI, but were subsequently diagnosed with PTSD in the 12 months immediately following diagnosis of a first mTBI. Although we only analyzed healthcare utilization in the 3-month periods immediately prior to and following diagnosis with mTBI, comorbidity status was drawn

from 12-month period pre- and post-diagnosis as rates of mental health symptoms have been shown to increase over time in SMs returning from deployment. Table 1 provides the demographic information of the study population.

Data Analysis

Healthcare utilization was calculated through counts of outpatient visits in the 90 days preceding and 90 days following the day of initial mTBI diagnosis, and median utilization was analyzed using nonparametric Wilcoxon signed rank tests as the data were not normally distributed, but the difference in utilization from pre-injury to post-injury was symmetrically distributed around the median. Effect size, *r,* was calculated from the Z statistic obtained from the Wilcoxon signed rank, as described by Fritz and colleagues (Fritz et al., 2011). The actual value of *r* indicated the magnitude of the effect size, with .5 as a large effect, .3 as a medium effect, and .1 as a small effect (J. Cohen, 1988). Health care utilization was analyzed 90 days prior to and 90 days following the diagnosis of mTBI, as the VA / DoD Clinical Practice Guideline for Treatment of mTBI / Concussion identifies 90 days as the period of time in which medical problems related to mTBI are expected to resolve. Health care utilization is compared by age, gender, and whether the mTBI diagnosis was related to military deployment in support of the Global War on Terror (GWOT), as indicated by ICD-9 code V15.52_2 (mild TBI, injury related to Global War on Terrorism (GWOT)), or unrelated to military deployment, as indicated by ICD-9 code V15.52_7 (mild TBI, injury not related to Global War on Terrorism (non-GWOT). Approximately 64% of SMs had no documentation of whether their injury was GWOT related or not.

Study Sample

The final study sample was 28,616 SMs, of which 74% (n= 21, 232) had mTBI_Only, 14.8% (n=4255) had a diagnosis of PTSD prior to mTBI, and 10.9% (n=3129) had a diagnosis of PTSD following mTBI. Service members 25 or older and females were more likely to have a diagnosis of PTSD prior to mTBI than following mTBI. Demographics are shown in Table 1.

RESULTS

Results include mean and median utilization. Mean utilization by each population subset was larger than median utilization, suggesting that the mean utilization values for each group of SMs were influenced by a small number of subject with utilization rates far above the group mean. Median utilization, therefore, may offer utilization estimates that are more representative of typical utilization by an individual SM, and mean utilization rates offer insight into the wide range of utilization by SMs. Pre-injury-and post-injury utilization, by group, is shown in Table 2. Mean utilization pre-injury and post-injury is represented in Figure 1.

Outpatient health care utilization by service members with mTBI_Only

Of all service members with mTBI, those with mTBI_Only had the lowest health care utilization pre- and post-injury, with a mean of 3.2($\pm$6) in the 90 days preceding injury and 7.6($\pm$17.4) visits post-injury. Median utilization rose from 2 visits pre-injury to 4 visits post-injury, a moderate increase ($Z=-65.05$, $p<.001$, $r=.32$). Approximately 72% of SMs with mTBI_Only had at least one outpatient visit in the three months prior to injury, and 88% of SM had at least one visit in the three months following injury. Median utilization by females increased from three visits pre-injury to five visits post-injury ($Z=-30.19$, $p<.001$, $r=.40$), compared to an increase from two visits pre-injury to four visits post-injury ($Z=-101.34$, $p<.001$, $r=.53$) by males. All mTBI_Only age groups had moderate increases in median utilization, as did

the GWOT and non-GWOT groups. Mean utilization by GWOT SMs increased from a pre-injury average of 3.5(±9.5) visits to a post-injury average of approximately 14(±30.8) visits. Median utilization by mTBI_Only GWOT SMs increased three-fold, from two visits pre-injury to six visits post-injury (Z=-30.5, p<.001, r=.44).

Outpatient health care utilization by service members with Pre-existing PTSD

Service members with pre-existing PTSD demonstrated far higher pre-injury health care utilization, than SMs with mTBI_Only or new onset PTSD, with a mean of 20.4(±21.7) visits. Median utilization increased from 14 visits pre-injury to 20 visits, representing a small-to-moderate (Z=-23.08, p<.001, r=.25) increase. Mean utilization increased to 29.5(±29.5) visits post-injury. Post-injury median utilization had a small-to-moderate increase for each age group, with the youngest SMs demonstrating the smallest median increase (*r=.19)* and SMs 45 or older demonstrating a moderate (*r=.29)* increase in utilization in the 90 days following injury. Males had a moderate increase from median of 14 visits pre-injury to 20 visits (Z=-22.53, p<.001, r=.30) post-injury. Females with pre-existing PTSD had a small-to-moderate increase in utilization, from a median of 16 visits pre-injury to a 21 visits post-injury (Z=-5.33, p<.001, r=.24). Service members with pre-existing PTSD with a war-related injury demonstrated a moderate increase in median utilization, from 14 visits pre-injury to 25.5 visits post-injury (Z=-22.95, p<.001, *r*=.36). Mean utilization by GWOT SMs with pre-existing PTSD was 20.8(±21.7) visits, increasing to 35.0(±31.5) visits post-injury. Median utilization by non-GWOT SMs from 16 visits pre-injury to 24 visits post-injury (Z=-7.78, p<.001, r=.36)

Outpatient health care utilization by service members with New Onset PTSD

Service members with new onset PTSD demonstrated substantial increases in utilization from the 90 days pre-injury to the 90 days post-injury, with a large increase from a pre-injury median of 3 visits, to a post-injury median of 17 visits (Z=-43.61, p<.001, r=.55). Mean utilization increased from 5.5(±11.4) visits pre-injury to 32.1(±41.6) visits post-injury. Although all age groups demonstrated a large increase in median utilization, SMs age 17-24 demonstrated the largest increase, from a pre-injury median of 2 visits, to a post-injury median of 20 visits (Z=25.91, p<.001, r=.56). Mean utilization increased from 5.3(±13.5) visits pre-injury to 38.6(±50.3) visits post-injury. SMs 25-34 increased from a mean of 5.3 visits pre-injury to 30(±39.5) visits post-injury. Median utilization by SMs 25-34 increased from two visits to 16 visits (Z=-27.7, p<.001, r=.55). Males and females each demonstrated large increases in utilization, from a median of 3 visits pre-injury to 18 visits post-injury for females (Z=-12.12, p<.001, r=.55) and 17 median visits for males (Z=-41.89, p<.001, r=.55). SMs with a war-related injury new onset PTSD demonstrated a large increase in utilization, from a pre-injury median of three visits to 23 visits (Z=-35.09, p<.001, r=.58) post-injury. Mean utilization increased from 5.6(±12.3) visits pre-injury, to 39(±46.2) visits post-injury. Non-GWOT SMs, also had a large increase in utilization, from a pre-injury median of 3 (mean 6±9.5) visits, to a post-injury median of 20 (mean 33.1±35.3) visits (Z=.12.75, p<.001, r=.57).

DISCUSSION

This study examines pre-injury and post-injury patterns of short-term health care utilization in SMs with a first diagnosis of mTBI in the military, subsets of which have PTSD prior to or following mTBI. Median pre-injury and post-injury utilization were highly influenced by

the presence or absence of premorbid or comorbid PTSD, although all SMs demonstrated at least a doubling of median utilization from pre-injury to post-injury. This is the first study to examine the impact of premorbid and comorbid PSTD on short-term healthcare utilization in active duty SMs with a first diagnosis of mTBI.

Most SMs with mTBI are expected to recover within a short period of time, which may be supported by the comparatively low utilization of outpatient care by mTBI_Only SMs, whose utilization rate is similar to that of active duty SMs screened for TBI (Amara et al., 2014; Cooper et al., 2011). Overall, median utilization for mTBI_Only SMs doubled in the post-injury period, suggesting that most SMs require some level of health care in the acute post-injury period. However, studies of veterans, in which mTBI likely no longer presents an acute injury, consistently display sustained higher utilization than veterans without mTBI, suggesting that SMs may continue to utilize health care long after the acute injury has passed (Drag et al., 2013; Taylor et al., 2015). Many VA studies include only veterans who sought care within the respective study periods, which may explain sustained utilization rates in these studies and reports, as veterans with ongoing health concerns continue to utilize care and those without ongoing concerns significantly decrease or cease utilization.

We did not examine the types of care sought by SMs in this study, so we do not know if utilization by SMs took place in primary care or outpatient specialty clinics, which could provide insight to why SMs are seeking care. The DoD mandates health care following TBI in some instances, so some SMs with mTBI_Only may have met the minimum requirement, and then no longer sought care (D. o. V. Affairs & Defense, 2015b). Some SMs members may have declined to use available health services due to perceived stigmatization, as has been previously

reported (Hoge et al., 2008). Additionally, given that the observed period of utilization fell within several of the peak deployment years of the Iraq and Afghanistan wars, some of the pre-injury and post-injury utilization may have resulted from required visits after problems were identified in pre-deployment or post-deployment screening required by the DoD. A longer period of analysis is needed to examine whether utilization increases or decreases over time, indicating if SMs received additional care or not.

Service members with pre-existing PTSD had the highest rate of pre-injury utilization, with a median of nearly five visits per month, indicating active engagement with MHS outpatient services. A moderate increase in utilization indicates that SMs with pre-existing PTSD seek additional care following mTBI, to a median of 20 visits in 90 days by the overall cohort, to a median of 25 visits for SMs with pre-existing PTSD and a war-related mTBI. The high post-injury utilization extends to SMs with new onset PTSD, with large increases in utilization of between a median of 17 post-injury visits by the overall cohort, to 23 visits by SMs with new onset PTSD and a war-related mTBI. The high rate of utilization by SMs with mTBI and PTSD likely has far-reaching effects in terms of cost to the MHS, military operational readiness, and personal cost to the individual SM.

One year direct outpatient cost to the MHS for mTBI is estimated at $618 to $1487 and $15,441 to $21,346 for acute hospital care, per patient (Tanielian & Jaycox, 2008). Additionally, deployment-related mental health conditions, such as PTSD, are estimated to cost between $120 and $131 million dollars per 50,000 SMs deployed (Tanielian & Jaycox, 2008). Considering that approximately 1 million active duty SMs deployed in support of the wars in Iraq and Afghanistan, the estimated total direct and indirect cost to the military is substantial. Beyond

financial considerations of treating mTBI and related mental health conditions is the impact on military operational readiness. At a median rate of 7-8 visits per month for SMs with a war-related mTBI with PTSD, individuals are away from their military units one to two days per month for medical treatment during the acute and post-acute phases following mTBI, and the long-term utilization of medical care by active duty SMs following mTBI is largely unknown. Previous investigations into the impact of mental health conditions found higher rates of attrition from the military by SMs with mental health concerns when compared to attrition by SMs with any non-mental-health medical condition (Garvey Wilson et al., 2009; Hoge et al., 2006). Additionally, SMs with mTBI have reported difficulty reintegrating to their military units, due to limitations in performing tasks, a perceived lack of empathy from their fellow SMs, and increased work absences (Hyatt et al., 2014)

An additional cost of mTBI to SMs is the personal cost of injury. In addition to physical injury, SMs with mTBI report higher levels of family stress and marital difficulties (Hyatt et al., 2014; Ponsford & Schonberger, 2010; Vanderploeg et al., 2007). Our study shows that younger SMs with new onset PTSD have the lowest rates of median utilization pre-injury and the highest rates of median utilization post-injury compared to other age groups, suggesting that younger SMs are among the most-symptomatic within our study population. Additionally, all age groups with new onset PTSD have large increases in outpatient utilization post-injury, suggesting that SMs with new onset PTSD went from being healthy individuals to needing high amounts of health care in a short period of time, indicating minimal lag in the onset of a need for health care. Previous work has shown early intervention in the course of PTSD may decrease or inhibit self-report symptoms upon re-evaluation, but results are mixed (Bisson, 2003; Foa, Keane, &

Friedman, 2003; S. M. Maguen, E.; Neylan, T. C.; Cohen, B. E.; Bertenthal, D.; & Seal, K. H., 2014). Additionally, adherence to prescribed treatment modalities may improve near-term symptomatology (Monson et al., 2006). The rapid increase in utilization by SMs with new onset PTSD may be limited to the short-term if treatment is initiated early, although this must be investigated in future studies. If early intervention in limiting PTSD progression is successful, mandatory treatment may be indicated, as chronic PTSD symptoms are resistant to treatment and younger veterans are less likely to initiate care early or to complete minimally adequate care (Harpaz-Rotem & Rosenheck, 2011; S. Maguen, Madden, et al., 2012).

Limitations

Several limitations exist in this study. First, SMs with mTBI, particularly from blast-related injury, are likely to have comorbid orthopedic and musculoskeletal injury, requiring surgical consultation and intervention, as well as physical and occupational therapy to restore functionality. An in-depth exploration of individual health care utilization by specialty clinic is needed in future research, particularly for SMs with blast-induced mTBI. Additionally, participants were assumed to have mTBI based on ICD-9-CM codes, which has substantial limitations. Previous studies have shown ICD-9 coding of mTBI to be inaccurate in terms of accurately identifying patients with an mTBI, particularly patients with other bodily trauma, as well as diagnosing mTBI in patients later found in interviews not to have an mTBI (Bazarian et al., 2006). Further, ICD-9 codes have found to overestimate and underestimate mTBI rates (Bazarian et al., 2006; Moss & Wade, 1996; Powell et al., 2008). We did not have access to lifetime mTBI history, so indication of a first diagnosis of mTBI is limited to time on active duty, and underestimates the number of SMs with a previous mTBI. Mild TBI is known to be vastly

underreported in civilian sectors due to injured persons not seeking care, and this is equally likely among military SMs. Finally, we did not look at inpatient utilization, which may affect the rate of outpatient utilization prior to, during, and following hospitalization, and has been shown to differ by gender in mTBI, particularly with combined comorbidities (S. Maguen, Cohen, et al., 2012).

CONCLUSIONS

The purpose of this study was to investigate short-term healthcare utilization by active duty SMs with a first diagnosis of mTBI in the military, with and without premorbid or comorbid PTSD. We found at least a doubling of median health care utilization by all SMs from pre-injury to post-injury, and substantially higher overall mean utilization, suggesting subsets within each group with high utilization. Service members with PTSD prior to mTBI were the highest utilizers of care pre-injury and post-injury, but SMs with new onset PTSD showed the largest increase in utilization. The findings of this study indicate overall low median utilization of outpatient rehabilitation, mental health, and neurology clinics, but high utilization of outpatient specialty clinics by a subset of service members. Future studies are needed to investigate implications of premorbid and comorbid PTSD, and other psychological and physical comorbidities, on the long-term outcomes of mTBI patients.

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Table 1: Characteristics of active duty SMs with a first diagnosis of mTBI, a subset of whom had a premorbid or comorbid diagnosis of PTSD

	mTBI_Only		Pre-exisitng PTSD		New Onset PTSD		Total	
	n	%	n	%	n	%	n	%
Overall	21232	74%	4255	15%	3129	11%	28616	
17-24	9124	43%	715	17%	1052	34%	10891	38%
25-34	8186	39%	1984	47%	1253	40%	11423	40%
25-44	3107	15%	1200	28%	661	21%	4968	17%
45-Over	815	4%	356	8%	163	5%	1334	5%
Male	18441	87%	3827	90%	2886	92%	25154	88%
Female	2791	13%	428	10%	243	8%	3462	12%
Non-GWOT	2199	10%	275	6%	252	8%	2726	10%
GWOT	3614	17%	2026	48%	1857	59%	7497	26%
Unknown	15419	73%	1954	46%	1020	33%	18393	64%

Pre-existing PTSD: SM had a diagnosis of PTSD within 12 months prior to first diagnosis of mTBI in the military

New onset PTSD: SM had no diagnosis of PTSD in the 12 months prior to a first diagnosis of mTBI in the military, but were subsequently diagnosed with PTSD in the 12 months following the initial mTBI diagnosis

Table 2. 90 day pre-injury and 90 day post-injury median utilization by service members with a pre-existing or new onset mental health condition

mTBI Only

		Pre		Post			
	n	Mean ±SD	Median (25th-75th)	Mean ±SD	Median (25th-75th)	Z	Effect Size
Overall	21232	3.2 ±6	2 (0-4)	5.1 ±6.1	4 (1-8)	-65.05	0.32
17-24	9124	2.9 ±5.7	2 (0-4)	7.1 ±18.6	3 (1-7)	-41.08	0.30
25-34	8186	3.0 ±6.2	2 (0-4)	7.5 ±16.7	4 (2-8)	-42.19	0.33
35-44	3107	3.9 ±5.9	2 (1-5)	8.5 ±16.4	5 (2-9)	-25.20	0.32
45-Over	815	5.2 ±7	3 (1-7)	10.2 ±14.9	6 (2-13)	-11.99	0.30
Male	18441	3 ±6.1	2 (0-4)	7.6 ±18.4	4 (1-7)	-101.34	0.53
Female	2791	4.4 ±5.3	3 (1-6)	7.4 ±9.7	5 (2-9)	-30.19	0.40
GWOT	3614	3.5 ±9.5	2 (0-4)	14.2 ±30.8	6 (3-12)	-30.51	0.36
Non-GWOT	2199	3.6 ±6.1	2 (1-4)	11.4 ±20.2	6 (3-12)	-29.33	0.44

Pre-existing PTSD

		Pre		Post			
	n	Mean ±SD	Median (25th-75th)	Mean ±SD	Median (25th-75th)	Z	Effect Size
Overall	4255	20.4 ±21.7	14 (7-27)	29.6 ±29.5	20 (9-40)	-23.08	0.25
17-24	715	19.8 ±22.6	13 (6-25)	20.3 ±21.3	17 (8-37)	-7.25	0.19
25-34	1984	20.3 ±21.1	14 (6-27)	30.1 ±30.3	21 (9-41)	-16.65	0.26
35-44	1200	20.5 ±22.3	14 (7-26)	29.5 ±29.3	20 (9-39)	-12.24	0.25
45-Over	356	22.2 ±20.5	16 (7.25-31.75)	32.8 ±30.2	23 (10-47.75)	-7.69	0.29
Male	2886	20 ±21.3	14 (6-26)	29.6 ±29.6	20 (9-40)	-22.53	0.30
Female	243	23.2 ±24.4	16 (8-28)	29.6 ±28.5	21 (9-41)	-5.33	0.24
GWOT	2026	20.8 ±21.7	14 (7-27)	35 ±31.6	25.5 (13-47)	-22.95	0.36
Non-GWOT	275	23.4 ±24.5	16 (7-33)	34.4 ±29.1	24 (12-51)	-7.78	0.33

New Onset PTSD

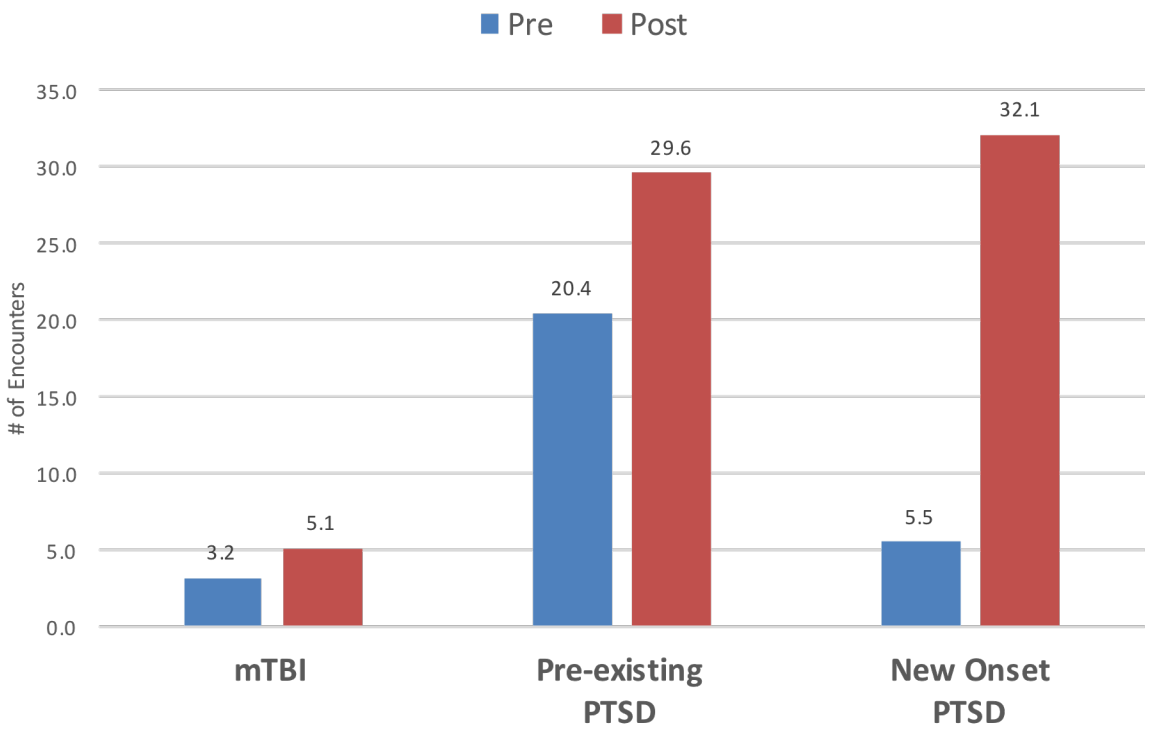
		Pre		Post			
	n	Mean ±SD	Median (25th-75th)	Mean ±SD	Median (25th-75th)	Z	Effect Size
Overall	3129	5.5 ±11.4	3 (0-6)	32.1 ±41.6	17 (7-39)	-43.61	0.55
17-24	1052	5.3 ±13.5	2 (0-5)	38.6 ±50.3	20 (8-48)	-25.91	0.56
25-34	1253	4.8 ±9.8	2 (1-6)	30.2 ±39.5	16 (7-37)	-27.73	0.55
35-44	661	6.4 ±10.7	3 (1-8)	26.4 ±30.7	16 (7-33)	-19.21	0.53
45-Over	163	7.8 ±10.4	4 (2-9)	27.5 ±25.7	18 (9-37)	-9.49	0.53
Male	2886	5.4 ±11.6	3 (0-8)	32.5 ±42.2	17 (7-41)	-41.89	0.55
Female	243	5.9 ±8.9	3 (1-8)	27.3 ±33.1	18 (8-34)	-12.12	0.55
GWOT	1857	5.6 ±12.3	3 (0-6)	38.9 ±46.2	23 (10-50.5)	-35.09	0.58
Non-GWOT	252	6 ±9.5	3 (1-7)	33.1 ±35.3	20 (10-44)	-12.75	0.57

mTBI_Only: SM had no diagnosis of a psychiatric health problem in the year prior to of following a first diagnosis of mTBI

PTSD_Pre: SM had a diagnosis of post-traumatic stress disorder within the year prior to a first diagnosis of mTBI

PTSD_New: SM had no diagnosis of post-traumatic stress disorder in the year prior to mTBI, but had a diagnosis of PTSD

Figure 1. Pre-injury and post-injury mean utilization by SMs with mTBI, mTBI with pre-existing PTSD, and mTBI with new onset PTSD. Mean utilization is reported in Table 2.



CHAPTER 4

Gender Differences in One-year Health Care Utilization by Active Duty Service Members with a first diagnosis of Mild Traumatic Brain Injury

ABSTRACT

Mild traumatic brain injury (mTBI) is a frequent cause of injury in active duty service members (SMs), up to 25% of who report post-concussive symptoms upon return from deployment. Women represent approximately 15% of active duty forces and comprise a significant percentage of deployed military personnel. As of 2013, women may serve in all direct combat roles, and Congress has mandated examination of gender-specific health care needs. Health care utilization following mTBI has been studied in veteran populations, but there is limited study of gender differences in health care utilization by active duty SMs. Through retrospective analysis of electronic health record data, we investigated gender-related differences in health care utilization by 46,247 active duty SMs with a first diagnosis of mTBI in the military. Median outpatient utilization in the 12 months prior to and following a first mTBI were compared using Wilcoxon signed rank test statistic Z and effect size, *r*. Our sample was 12.6% female, and 33.5% of SMs had deployment-related mTBI. Median outpatient health care utilization by all SMs doubled, with males increasing from a median of 9 visits pre-injury to 19 visits post-injury ($Z=-107.18$, $p<.001$, $r=.38$). Mean utilization by males increased from 16.8($\pm$26.5) visits pre-injury to 44($\pm$71) visits post-injury. Male SMs with a war-related injury increased from 9 visits pre-injury to 40 visits in the year post-injury ($Z=-78.1$, $p<.001$, $r=.52$). Females increased median utilization from 17 visits pre-injury to 26 visits post-injury ($Z=-30.35$, $p<.001$, $r=.28$). Mean utilization by females increased from 26(SD$\pm$30) visits pre-injury to 43($\pm$55) visits post-injury. Female SMs with a war-related mTBI increased from 16 visits pre-injury to 51 visits post-injury ($Z=-17.3$, $p<.001$, $r=.50$). Utilization peaked in the three months immediately following injury, with an average of 15($\pm$27) visits by males and 13($\pm$18) visits by females. Median utilization of mental health, rehabilitation, and neurology clinics overall was very low, but substantially higher by SMs with a war-related mTBI, suggesting bodily injury beyond mTBI and concurrent psychological health conditions in GWOT SMs.

Beginning in 2013, the Department of Defense (DoD) rapidly expanded the breadth of military occupations open to female service members (SMs), allowing women to serve in all direct combat roles (Congress, 2008a; Congress, 2012a). Women represent approximately 15% of active duty forces and comprised 11% of military personnel who deployed to Iraq and Afghanistan (Center., 2011; O. o. t. D. A. S. o. D. f. M. C. a. F. P. O. M. F. Department of Defense, 2016). Prior to opening all military occupational roles to women, Congress called for examination of gender-specific health care needs, particularly behavioral health services,

highlighting the need for research of gender-related differences in health seeking behavior(Congress, 2008b; Congress, 2012b).

Active duty service members typically receive care within the Military Health System (MHS), and the DoD maintains comprehensive databases of injury statistics and health care received. Traumatic brain injury has been termed a signature injury of Operation Enduring Freedom and Operation Iraqi Freedom (OEF/OIF), and is a frequent and prevalent injury in the deployed and non-deployed active duty population (Center, 2016; Hoge et al., 2008; Tanielian & Jaycox, 2008). Of known TBI cases, 80% are considered mild TBI (mTBI), characterized by the DoD as a TBI with either no loss of consciousness or loss of consciousness for less than 30 minutes, post traumatic amnesia lasting less than 24 hours, and a TBI with an absence of radiographic abnormality (D. o. V. Affairs & Defense, 2016; Center, 2016). The prevalence of TBI among OEF/OIF veterans is estimated between 12-20% (O. o. t. U. S. o. D. f. P. a. R. Department of Defense, 2012; K. M. Iverson et al., 2011), and up 25% of SMs will report post-concussive symptoms at three month post-deployment (Schwab et al., 2017). Among females, 10-13% of Iraq and Afghanistan veterans receiving care within the Veterans Health Administration (VHA) screen positive for possible TBI or a history of TBI(Hendricks et al., 2013; K. M. Iverson et al., 2011).

Following mTBI, most people are expected to recover within a short period of time, however, neurologic, cognitive, and physical symptoms may persist for days to months or longer, requiring ongoing medical treatment(Bolzenius et al., 2015; Schneiderman et al., 2008; Stein et al., 2016; Terrio et al., 2009). Previous studies have highlighted gender differences in health care utilization following mTBI, in which females utilize higher levels of outpatient

primary and specialty care than males, and incur slightly higher outpatient and pharmacy costs(Chatterjee et al., 2009; Duggal et al., 2010; Milliken et al., 2007; Rogers et al., 2014).

Identification and treatment of active duty SMs with mTBI is important to military operational readiness, as ill or injured SMs may not be deployable. Additionally, SMs with mTBI are at higher risk for further injury or development of comorbid conditions such as PTSD or depression, impacting long-term operational readiness(Carlson et al., 2010; B. E. Cohen et al., 2010; Vanderploeg et al., 2009; Vanderploeg et al., 2007). As the active military adapts to the expanded role of female SMs in combat units, a better understanding of gender-related differences in long-term health seeking behavior is crucial to planning current and future medical treatment of SMs with mTBI. Further, identification of SMs either at-risk for poor clinical outcomes or who fail to respond to available treatment modalities is equally important. Therefore, the purpose of this study is to quantify one-year health care utilization by male and female SMs prior to and following a first mTBI, and to identify gender-related differences in the pattern of utilization. The research questions we investigated were, 1) what is pattern of health care utilization in the 12 months prior to injury in active duty SMs with a first diagnosis of mTBI, 2) what is the pattern of health care utilization in 12 months following injury by active duty SMs with a first diagnosis of mTBI, and 3) how does health care utilization differ pre-and post-injury by gender?

METHOD

Data Set

This study is a retrospective analysis of electronic health record (EHR) data of active duty SMs with a first diagnosis of mTBI in the military. The DoD EHR contains longitudinal medical record information of direct care provided by the MHS as well as care purchased through civilian networks. The original dataset was compiled by the National Intrepid Center of Excellence (NICoE) at Walter Reed National Military Medical Center under an approved IRB protocol. The NICoE dataset included all outpatient encounters between 2006-2014 by active duty SMs with a diagnosis of mTBI indicated by *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes, and included SMs with at least one year of active duty service prior to and following the index diagnosis of TBI.

Study Sample

The population included in the study was all U.S. military personnel who utilized ambulatory care within the MHS between 2006-2014 and had a documented diagnosis of first mTBI, as indicated by ICD-9-CM code 850.0 (concussion with no loss of consciousness) or 850.11 (concussion with loss of consciousness of 30 minutes or less). The study sample was limited inclusion to ICD-9-CM codes 850.0 and 850.11 as these codes are consistent with the VA / DoD definition of mTBI. Service members with a diagnosis of moderate or severe TBI, as well as SMs with a history of a previous TBI documented in the EHR were excluded from the study, as were SMs with a subsequent TBI within 12 months of the initial mTBI diagnosis. As the focus of this study is one-year health care utilization of MHS clinics by active duty SMs following a first mTBI, Reserve Component SMs, National Guard SMs, and non-military SMs eligible for MHS care were excluded.

Data Analysis

Healthcare utilization was calculated through a count of MHS-provided outpatient visits in the 12 months preceding and 12 months following the date of a mTBI diagnosis. Pre-injury and post-injury median health care utilization was analyzed through non-parametric Wilcoxon Signed Ranks, as our data was not normally distributed, but the distribution of the difference in utilization from pre-injury to post-injury was symmetrical. Group means and median are reported by age, gender, and if the injury was related to military deployment in support of the Global War on Terror (GWOT) as designated by ICD-9 code V15.52_2 (GWOT / war-related) or V15.52_7 (non-GWOT) in the EHR. Effect sizes (*r)* were calculated from the *Z* statistic of the Wilcoxon signed rank test as described by Fritz and colleagues (Fritz et al., 2011). The actual value of *r* indicates the effect size, with .5 as a large effect, .3 as a medium effect, and .1 as a small effect(J. Cohen, 1988).

The final sample consisted of 46,247 SMs and was 87.4% male, and the majority of our sample was under 35 years old (n=36,952). Female SMs were more likely to have been diagnosed with a first mTBI between the ages of 17-24 (44.9%) compared to males (39.3%). Males were most likely to have been in the Army or Marines, females were most likely to have been in the Air Force. Approximately 26% of the sample had a deployment-related mTBI, with males (28.5%) more likely to have a deployment-related injury compared to females (10.1%), but 63% of our sample did not have a deployment status documented. Demographic information is shown in Table 1.

RESULTS

Results include mean and median utilization. Mean utilization was higher than median utilization for each category of utilization analyzed, due to a small subset of SMs with high

utilization. Median utilization, therefore, may offer a more accurate representation of the typical utilization by an individual SM in the pre-injury and post-injury timeframes, but mean utilization represents the broad range of utilization by SMs. One-year pre-injury and post-injury utilization totals, with effect size, are shown in Table 2 and Figure 1, and utilization by three-month interval is shown in Table 3 and Figure 2. Utilization of primary care and outpatient specialty care is shown in Table 4.

One-year Pre-and Post-injury Outpatient Utilization

Overall utilization from one-year pre-injury to one-year post-injury increased significantly by all SMs. Males utilized less median care in both the pre-injury and post-injury periods, but had a moderate increase in post-injury utilization compared to a small-to-moderate increase in post-injury utilization by females. Median utilization by males increased from 9 visits to 40 visits ($Z=-107.18$, $p<.001$, $r=.38$), with a pre-injury mean utilization rate of 16.8($\pm$26.5) visits and post-injury rate of 44($\pm$71) visits. Median utilization by females increased from 17 visits pre-injury to 26 visits post-injury ($Z=-30.35$, $p<.001$, $r=.28$). Mean utilization by females was 26($\pm$30) visits pre-injury and 43($\pm$55) visits post-injury. Approximately 95% of SMs had at least one outpatient visit in the year prior to injury and 98% of SMs had at least one visit in year following injury.

Male SMs age 34 or younger had moderate increases in median utilization, from 7-9 visits pre-injury to 15-20 visits post-injury, and female SMs 34 or younger had small-to-moderate increases in median utilization from 17 visits pre-injury to 24-25 visits post-injury. All male age groups demonstrated moderate effect sizes and all female age groups demonstrated

small-to-moderate increases in utilization. Effect sizes are reported in Table 1 for age groups by gender.

Male SMs with a war-related mTBI (GWOT) had the largest increase in utilization from a median of 9 visits pre-injury 40 visits post-injury (Z=-78.1, p<.001, r=.52). Mean utilization by male GWOT SMs was 19.5(±31.1) visits pre-injury, and 77.2(±97.1) visits post-injury. Female GWOT SMs also had a large increase in utilization from a median of 16 visits pre-injury to 51 visits post-injury (Z=-17.3, p<.001, r=.50). Mean utilization by GWOT females was 24.5(±28.7) visits pre-injury and 81(±87) visits post-injury. Approximately 95% of GWOT SMs had at least one outpatient visit prior to injury, compared to 99.5% post-injury. Non-GWOT SMs had higher pre-injury median utilization for both males and females, but lower post-injury median utilization, although non-GWOT SMs of both genders too had large increases in utilization.

Health Care Utilization by 3 month Increments

Overall utilization by the study sample (n=46,247) was highest in the 3 month periods immediately prior to and following diagnosis with mTBI as shown in Table 3. Pre-injury median utilization for the study sample in the 90 days prior to diagnosis was 3 visits (mean 6±12) and median utilization in 90 days following diagnosis was 6 visits (mean 15±26), representing a moderate increase in utilization (r=.35).

Males had a median utilization of 1-3 visits (mean 3-6) in each 3-month period prior to diagnosis, and peak utilization of 6 visits (mean 15±27) in the 3 months immediately following diagnosis, before decreasing utilization to a median of 3 visits (mean 9±18) by post-injury month 9. Females demonstrated higher pre-injury and post-injury median utilization in each

three-month interval, utilizing a median of 3-4 visits (mean 6-8) in each interval prior to diagnosis with mTBI. Post-injury median utilization by females peaked at 7 visits (mean 13±18) in the 90 days following diagnosis, and gradually tapered to a median of 5 visits (mean 10±15) by month 12, post-injury. Both males and females increased utilization with age in the pre-injury and post-injury periods.

Service members with a war-related mTBI had the highest post-injury median utilization, with GWOT males demonstrating a median utilization of 12 visits (mean 26±38) in the three months immediately following diagnosis and a median of 9 visits (mean 19±26) in months 4-6 post-mTBI, before declining to a median of 6 visits (mean 15±23) by month 12. Similarly, GWOT females had a peak median utilization of 14 visits (mean 25±28) in the three months immediately following diagnosis and a median of 12 visits (mean 22±26) at month 6, before declining to a median of 8 visits (mean 17±23) by month 12.

One-year Pre-and Post-injury Outpatient Utilization by Clinics

Overall median pre-injury and post-injury utilization by outpatient specialty clinics was very low, with median pre-injury utilization of rehabilitation, mental health, neurology clinics of zero visits for both males and females, as shown in Table 4. Approximately 87% of SMs had primary care visit pre-injury, and 92% post injury. Rehabilitation and mental health clinic utilization increased from 36-38% of SMs pre-injury, to 53-55% of SMs post-injury. Neurology utilization increased from 11% of SMs pre-injury, to 27% of SMs post-injury. Mean utilization of rehabilitation and mental health clinics was 3-4 visits, and mean utilization of neurology clinics was approximately .25 visits. Post-injury median utilization of neurology clinics remained zero,

and median utilization of rehabilitation and mental health clinics rose to one visit. Males averaged 10.7(±30.5) rehabilitation visits, 9.8(±11.6) mental health visits, and 2.2(±8.7) neurology visits, and females averaged 8.2(±20) rehabilitation visits, 8.7(±21.8) mental health visits, and 1.3(±5) neurology visits in the year post-injury.

Utilization of outpatient rehabilitation and mental health clinics was highest among GWOT SMs, with a median post-injury utilization rate of 4 rehabilitation visits (mean 19.7±44.7) and 6 mental health visits (mean 18.2±32.5) by GWOT males, and 6 rehabilitation (mean 18±33.3) and 6 mental health visits (mean 18.7±31) by GWOT females. Approximately 69% of male GWOT and 74% of female GWOT used rehabilitation clinics, 80% of GWOT males and 81% of GWOT females used mental health clinics, and 48% of GWOT males and 54% of GWOT females had one or more neurology encounters in the post-injury period.

DISCUSSION

The purpose of this study was to examine gender-related differences in health care utilization by active duty military SMs in the year prior to and year following first diagnosis of a mTBI in the military. We present an analysis of cumulative pre-and post-injury health care utilization, utilization by in three month increments pre- and post-injury, and one-year utilization of primary care and outpatient specialty clinics prior to and following diagnosis with mTBI.

One-year Health Care Utilization

Health care utilization in the 12 months preceding mTBI is higher for women than men in each quarter, and utilization increases with age, findings that are consistent with previous studies of health care utilization by veterans with an mTBI (Leslie et al., 2011). However, the

magnitude of increase is slightly higher by SMs under age 35 than SMs 35 or older. In our study, median utilization by our overall sample doubled from three visits in the 90 days immediately prior to mTBI to six visits in the 90 days immediately following mTBI. Male and female SMs each demonstrated a similar rapid increase in utilization in the three months following diagnosis with mTBI, but males decreased utilization more quickly than female SMs, who sustained median utilization through the latter half of the post-injury year. Although reasons for outpatient utilization are unknown, females may have prolonged or different symptomatology (K. M. Iverson et al., 2011), better adherence to treatment protocols (Seal et al., 2010), or the higher level of sustained utilization may represent a "new normal," as post-injury median utilization after six months, although slightly higher, is within one to two visits of pre-injury median utilization for each age group, and similar to median utilization rates consistently reported by the VHA (Taylor et al., 2014; Taylor et al., 2015; Taylor et al., 2012).

Most people are expected to recover within weeks to several months following mTBI (Carroll et al., 2004; Dikmen, Machamer, Finn, & Temkin, 2010), but previous studies of military personnel suggest 5-15% experience postconcussive symptoms for months or longer (Schneiderman et al., 2008; Stein et al., 2016; Terrio et al., 2009). In our study, peak health care utilization occurs within 3 months of injury, and then gradually declines to within one to two visits of pre-injury rates of outpatient utilization. Based upon the return to near-pre-injury levels of utilization, and low median utilization of outpatient specialty clinics findings suggest that most SMs do recover within months of injury, or stop utilizing high levels of health care services.

War-related mTBI

Despite the overall low median utilization of outpatient specialty clinics, SMs with a war-related injury use substantially more care in the year following mTBI, with median utilization by males at 40 visits and median utilization by females at 51 visits in the year post-injury. Age-related differences stand out as well, with the youngest GWOT SMs of both genders demonstrating the largest increases in utilization. Additionally, SMs with a war-related injury utilize significantly more mental health care than non-GWOT SMs and sustain high median utilization through the entire post-injury period studied, with a median rate of utilization double the within-gender median rate for the first six months post-injury. Prior to diagnosis with mTBI, GWOT SMs of both genders had median utilization rates equal to the within-gender median. Psychological comorbidity such as post-traumatic stress disorder (PTSD), depression, and substance use disorders likely contribute to the sustained high-rate of healthcare utilization, as reported in previous studies (B. E. Cohen et al., 2010; Drag et al., 2013; Kehle-Forbes et al., 2016), and supported by the higher mean and median utilization of mental health clinics by GWOT SMs. Additionally, GWOT SMs have an mTBI documented in the EHR as occurring while deployed, and deployment and combat exposure are known to be strongly associated with development of mental health disorders (Hoge et al., 2006; Hoge et al., 2008; Kang et al., 2003), lending further support for high utilization of mental health clinics by GWOT SMs, as is the high prevalence of the polytrauma clinical triad of pain, TBI, and PTSD in veterans of Iraq and Afghanistan (Lew et al., 2009) which may explain high concurrent utilization of rehabilitation clinics and mental health services by GWOT SMs in our study.

The pattern of utilization by SMs with a war-related injury, compared to SMs with a non-war-related injury, is suggestive of a difference in post-mTBI recovery. Higher utilization by

younger GWOT SMs, and higher utilization of mental health and rehabilitation clinics overall by GWOT SMs may indicate significant psychological health problems and noncephalic injury. Long-term studies of GWOT SMs, both in the MHS and VHA system, is necessary to better understand long-term clinical outcomes and daily functioning of these SMs, as well as the impact of early intervention and available treatment modalities.

Limitations

Several limitations of this study should be considered. First, the we intentionally used a definition of mTBI consist with the VA / DoD guidelines for determination of injury severity, which limited inclusion to two ICD-9 codes. Previous studies have used a broader range of ICD-9 codes as a definition of mTBI, and the narrow definition of mTBI in our study limits generalizability to the larger mTBI population. Additionally, use of ICD-9 coding of mTBI has been shown to both overestimate and underestimate the prevalence of injury, lack specificity, and inaccurately diagnose individuals who did not have an mTBI or who had traumatic bodily injury in addition to an mTBI (Bazarian et al., 2006; Moss & Wade, 1996; Powell et al., 2008).

Another limitation inherent to use of EHR records is missing data. Approximately 63% of our study sample had no documentation of deployment status at the time of injury. This large number of SMs with an unknown deployment status limits comparison of the rate of utilization by SMs with a known GWOT or non-GWOT injury. Our study showed higher rates of outpatient clinic by SMs with a documented GWOT or non-GWOT code, but SMs with more frequent clinical encounters may have more complete documentation of the initial injury, as additional evidence may be gathered through subsequent visits beyond initial diagnosis.

Utilization of health care by SMs was assumed to be voluntary and self-determined, but the DoD mandates clinical evaluation following potential TBI-causing events in a deployed environment Additionally, SMs are required to complete screening evaluations prior to following deployment, with a requirement for multiple post-deployment evaluations in many instances. The administrative requirements to evaluate injured SMs, and screen operationally deployed SMs, likely increases the mean and median utilization of health care in our sample. Additionally, evaluation of mTBI and screening of SMs pre-and post-deployment may serve as a catalyst for further health care utilization, as SMs are referred or directed to additional clinical evaluation.

Further, we did not account for psychological or physical premorbidities and comorbidities known to be commonly associated with mTBI. The operational tempo of the wars in Iraq and Afghanistan resulted in multiple and / or lengthy deployments by individual SMs. As indicated in the discussion, exposure to combat is associated with high rates of psychological health problems, and combat-related TBI that results in persistent postconcussive symptoms is likely to occur concurrently with PTSD and pain.

Finally, our analysis did not account for lifetime history of mTBI. Mild TBI is known to be vastly under-reported in civilian populations, and individuals with mTBI that met our narrow definition of injury, were likely less inclined to seek care following injury than individuals with a more severe form of mTBI. Our analysis likely did not include many SMs with a first mTBI who did not seek care, and thus had no documented injury, as well as individuals who had a TBI prior to military service.

Future Studies

Future studies are needed to address remaining gaps in our understanding of health care utilization by active duty SMs with a first diagnosis of mTBI. The difference in mean and median utilization by SMs is indicative of a subset of high utilizers of health care that needs additional analysis to characterize high utilizers of care and to differentiate reasons for use of health services. Additionally, the relationship between short-term and one-year utilization is poorly understood. Early intervention in psychological health conditions has shown to reduce symptomatology and improve outcomes, and the same may be true for SMs with an mTBI. Quantitative analysis is an efficient means to estimate the amount of health care utilization by an individual, but cannot determine an individual's reason for seeking care, which may be further derived through qualitative or a mixed-methods analysis.

Conclusions

The purpose of this study was to investigate the change in pre-injury and post-injury outpatient health care utilization in the population of active duty SMs diagnosed with a first mTBI. This study is an important step to understand how active duty men and women differ in utilization of health care following injury, and provides important evidence of utilization of primary care, rehabilitation, mental health, and neurology clinics by SMs diagnosed with a first mTBI, an important consideration in the treatment of an injury that is frequent and prevalent in both military and civilian populations. Future studies are needed to address possible relationships between patterns of short-term utilization and long-term health outcomes, particularly in war-injured SMs.

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Table 1: Characteristics of active duty SMs with a first diagnosis of mTBI in the military

	Male		Female		Total	
	n	%	n	%	n	%
Overall	40404	87%	5843	13%	46247	
Age						
17-24	15898	39%	2623	45%	18521	40%
25-34	16263	40%	2168	37%	18431	40%
35-44	6626	16%	788	13%	7414	16%
45-Over	1617	4%	264	5%	1881	4%
Service						
USA	24844	61%	2920	50%	27764	60%
USAF	5379	13%	1503	26%	6882	15%
USN	4338	11%	1016	17%	5354	12%
USMC	5843	14%	404	7%	6247	14%
Deployment Status						
GWOT	11524	29%	589	10%	12113	26%
Non-GWOT	4156	10%	713	12%	4869	11%
Unknown	24724	61%	4541	48%	29265	63%

GWOT: Global War on Terrorism, representing SMs with a deployment-related

Non-GWOT: SMs with a non-deployment-related mTBI

Table 2. One year pre-injury and post-injury median utilization by male and female service members

	Male				Female			
	N	Pre	Post	Effect Size	N	Pre	Post	Effect Size
Total by Gender	40404	9	19	0.38	5843	17	26	0.28
Age								
17-24	15898	7	15	0.38	2623	17	24	0.28
25-34	16263	9	20	0.39	2168	17	25	0.29
35-44	6626	12	26	0.36	788	20	29.5	0.27
45-Over	1617	15	29	0.33	264	25	37	0.25
Deployment Status								
non-GWOT	4156	10	27	0.46	713	21	43	0.44
GWOT	11524	9	40	0.52	589	16	51	0.50
Unknown	24724	8	13	0.26	4541	17	22	0.14
Non-GWOT by Age								
17-24	1788	9	25	0.48	331	19	39	0.43
25-34	1585	10	27	0.46	250	21	42	0.43
35-44	624	12	35	0.46	99	20	61	0.49
45-Over	159	17	37	0.39	33	36	56	0.36
GWOT by Age								
17-24	3491	6	38	0.55	160	14	41.5	0.54
25-34	5176	9	37	0.51	273	14	48	0.50
35-44	2325	13	44	0.49	120	24	67	0.48
45-Over	532	20	55.5	0.47	36	27.5	78	0.51

Pre-injury to post-injury comparisons using non-parametric Wilcoxon Signed Ranks

Statistical significance: p<.001 for all results

Table 3. One year pre-injury and one-year post-injury mean and median utilization by 3-month intervals

	Months prior to (pre) and following (post) first mTBI diagnosis in the DoD EHR									
	12 months Pre	9 months Pre Mean	6 months Pre Mean	3 months Pre Mean	3 months Post	6 months Post	9 months Post	12 months Post	Total Pre Mean	Total Post Mean
Overall (n=46,247)	4 (2)	4 (2)	4 (2)	6 (3)	15 (6)	11 (4)	10 (3)	9 (3)	18 (10)	44 (20)
Gender										
Male	3 (1)	3 (1)	4 (1)	6 (3)	15 (6)	11 (4)	9 (3)	9 (3)	17 (9)	45 (19)
Female	6 (3)	6 (3)	6 (4)	8 (4)	13 (7)	11 (6)	10 (5)	10 (5)	26 (17)	43 (26)
Male by Age										
17-24	3 (1)	3 (1)	3 (1)	5 (2)	13 (5)	9 (3)	8 (2)	8 (2)	13 (7)	39 (15)
25-34	3 (1)	3 (1)	4 (1)	6 (3)	15 (6)	12 (4)	10 (3)	9 (3)	17 (9)	46 (20)
35-44	4 (2)	5 (2)	6 (2)	8 (4)	17 (8)	13 (5)	11 (4)	10 (4)	23 (12)	50 (26)
45-Over	5 (2)	6 (2)	7 (3)	10 (5)	20 (11)	15 (6)	12 (4)	11 (4)	28 (15)	58 (29)
Female by Age										
17-24	5 (3)	5 (3)	6 (4)	7 (4)	11 (7)	10 (5)	9 (5)	9 (5)	23 (17)	39 (24)
25-34	6 (3)	6 (3)	7 (4)	8 (4)	13 (7)	11 (6)	10 (5)	9 (5)	26 (17)	43 (25)
35-44	7 (4)	6 (4)	8 (4)	10 (6)	16 (8)	13 (6)	11 (6)	11 (5)	30 (20)	52 (29.5)
45-Over	9 (5)	10 (5)	10 (6)	12 (6)	19 (11)	15 (8)	13 (7)	12 (6)	40 (25)	59 (37)
Male by Deployment Status										
Non-GWOT	3 (2)	4 (2)	4 (2)	6 (3)	18 (9)	13 (5)	12 (4)	12 (4)	17 (10)	55 (27)
GWOT	3 (1)	3 (1)	4 (1)	8 (4)	26 (12)	19 (9)	16 (7)	15 (6)	19 (9)	77 (40)
Female by Deployment Status										
Non-GWOT	7 (4)	7 (4)	8 (5)	10 (6)	20 (12)	17 (10)	15 (8)	14 (7)	31 (21)	66 (43)
GWOT	6 (3)	6 (2)	6 (3)	10 (5)	25 (14)	22 (12)	18 (9)	17 (8)	28 (16)	81 (51)

All results obtained using non-parametric Wilcoxon Signed Ranks with statistical significance of $p < .001$

Pre-injury and Post-injury median and mean may not equal the sum of the individual intervals due to rounding

Table 4: One-year pre and post-mTBI mean and median health care utilization by outpatient clinics

Male

	Primary Care		Rehabilitation		Mental Health		Neurology		All Other	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	Mean (median)		Mean (median)		Mean (median)		Mean (median)		Mean (median)	
Overall	5.9 (4)	9.5 (6)	3.1 (0)	10.7 (1)	3.3 (0)	9.8 (1)	.24 (0)	2.2 (0)	4.1 (2)	11.7 (3)
Age										
17-24	4.6 (3)	8 (5)	2.1 (0)	10.1 (0)	2.1 (0)	7.6 (1)	.18 (0)	.71 (0)	3.2 (1)	10.7 (3)
25-34	5.5 (4)	9.8 (6)	3.1 (0)	10.7 (1)	3.8 (0)	11.1 (1)	.25 (0)	2.2 (0)	4.1 (2)	11.8 (3)
35-44	7.3 (5)	11.3 (8)	4.9 (0)	11.6 (2)	4.7 (0)	11.7 (1)	.33 (0)	2.8 (0)	5.3 (2)	12.5 (4)
45-Over	9.1 (6)	12.5 (9)	5.9 (1)	13.5 (3)	4.2 (0)	11.4 (1)	.46 (0)	2.9 (0)	8.1 (3)	17.4 (6)
Deployment Status										
Non-GWOT	5.7 (4)	10.3 (7)	3.5 (0)	14.5 (3)	2.7 (0)	10.4 (2)	.22 (0)	3.8 (1)	4.5 (2)	15.4 (5)
GWOT	5.6 (3)	13.5 (9)	3.8 (0)	19.7 (4)	4.4 (0)	18.2 (6)	.38 (0)	4.7 (0)	4.9 (2)	20.4 (7)

Female

	Primary Care		Rehabilitation		Mental Health		Neurology		All Other	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	Mean (median)		Mean (median)		Mean (median)		Mean (median)		Mean (median)	
Overall	9.7 (8)	12.4 (10)	4.0 (0)	8.2 (1)	4.1 (0)	8.7 (1)	.25 (0)	1.3 (0)	6.7 (3)	11.3 (5)
Age										
17-24	9.3 (8)	11.8 (9)	3.1 (0)	6.6 (1)	3.5 (0)	7.5 (0)	.16 (0)	1.1 (0)	5.6 (3)	10.4 (4)
25-34	9.5 (8)	12.3 (10)	3.8 (0)	8.5 (1)	4.4 (0)	8.9 (1)	.26 (0)	1.3 (0)	6.9 (3)	11.2 (5)
35-44	10.9 (9)	14.2 (11)	6 (1)	10.3 (3)	4.8 (0)	11.9 (1)	.45 (0)	1.9 (0)	7.1 (3)	12.6 (5)
45-Over	11.8 (10)	14.6 (11)	9.1 (2)	14.5 (5.5)	6.1 (0)	10.3 (1)	.58 (0)	1.8 (0)	12.6 (5)	17.4 (8)
Deployment Status										
Non-GWOT	10.5 (9)	15.7 (12)	5.6 (1)	14.9 (5)	5.4 (0)	14.5 (3)	.37 (0)	3.6 (1)	8.2 (4)	16.2 (8)
GWOT	9 (7)	17.2 (12)	4.8 (0)	18 (6)	5.6 (1)	18.7 (6)	.46 (0)	4.2 (1)	7.3 (3)	21.5 (11)

All results calculated using non-parametric Wilcoxon Signed Ranks

All values significant at $p<.001$

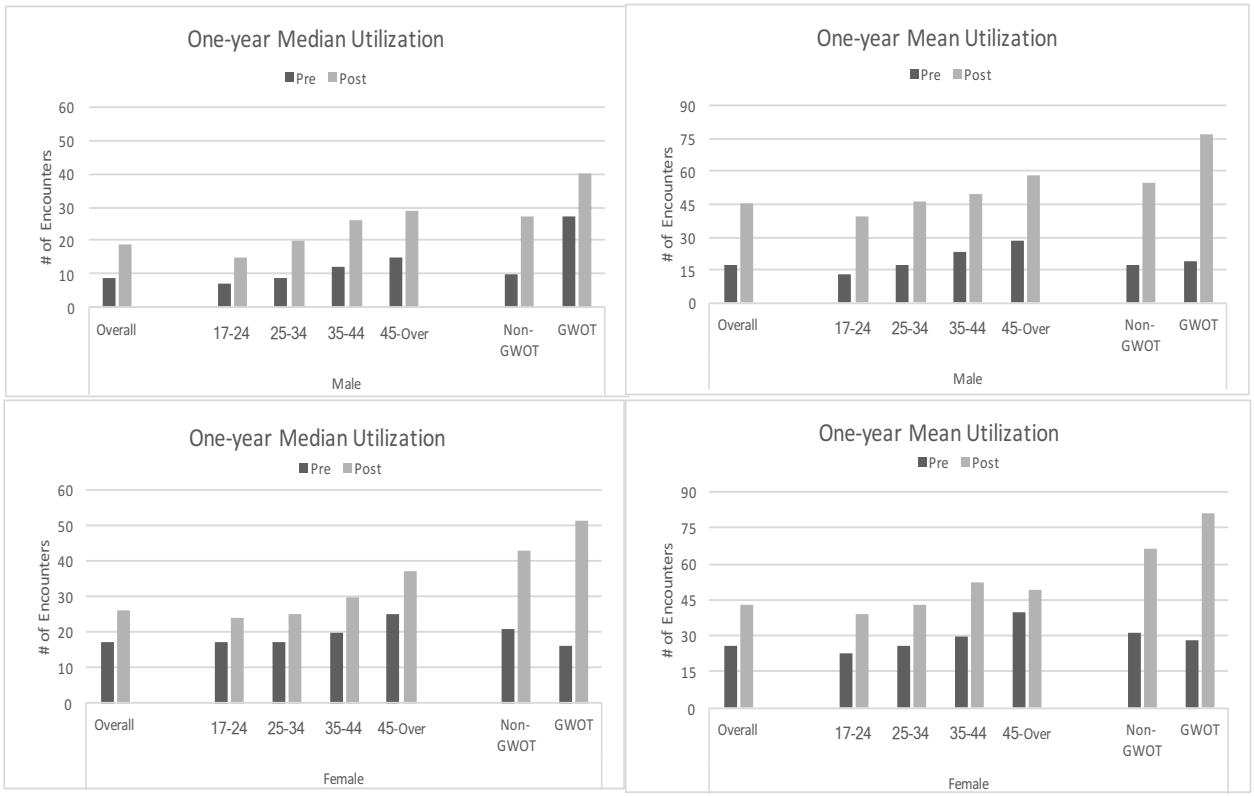
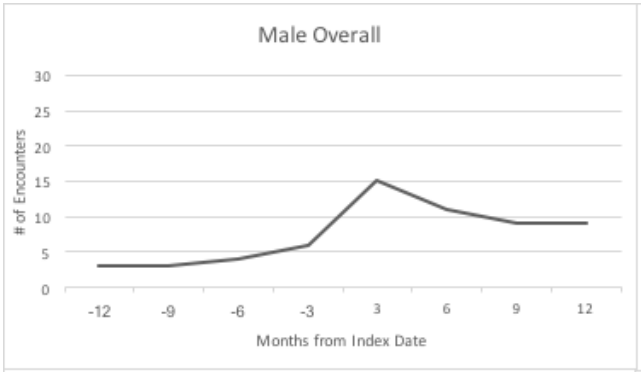
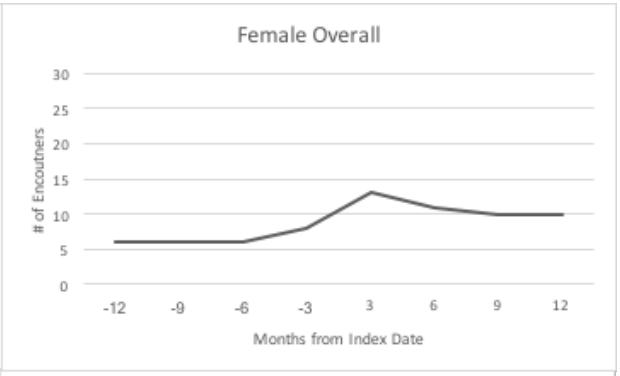
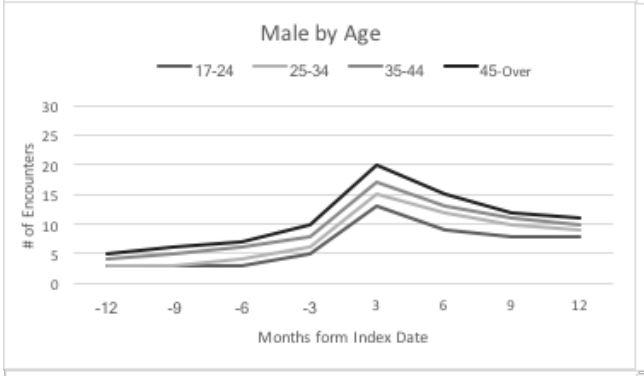
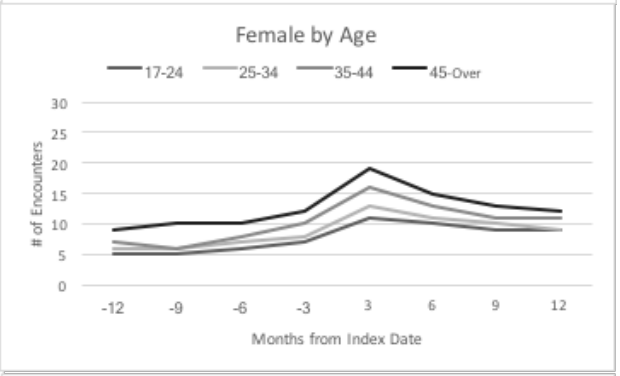


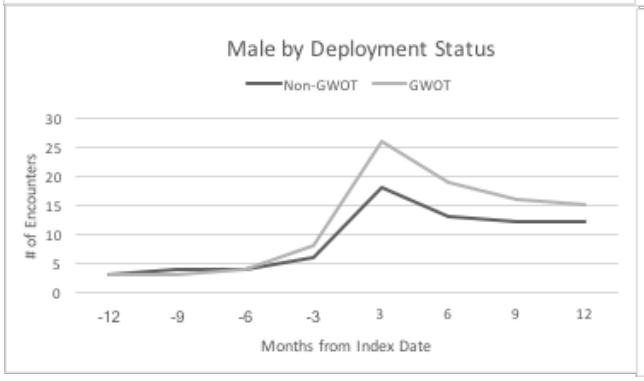
Figure 1: One year mean and median health care utilization by gender. Male pre-injury and post-injury utilization is displayed in the upper panels. Female pre-injury and post-injury utilization is displayed in the lower panels. Utilization totals are shown in Table 2.

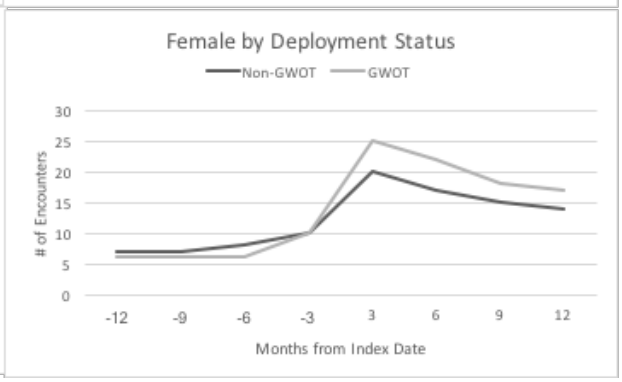

Male Overall
# of Encounters
30
25
20
15
10
5
0
-12
-9
-6
-3
3
6
9
12
Months from Index Date


Female Overall
# of Encoutners
30
25
20
15
10
5
0
-12
-9
-6
-3
3
6
9
12
Months from Index Date


Male by Age
17-24
25-34
35-44
45-Over
# of Encounters
30
25
20
15
10
5
0
-12
-9
-6
-3
3
6
9
12
Months form Index Date


Female by Age
17-24
25-34
35-44
45-Over
# of Encounters
30
25
20
15
10
5
0
-12
-9
-6
-3
3
6
9
12
Months from Index Date


Male by Deployment Status
Non-GWOT
GWOT
# of Encounters
30
25
20
15
10
5
0
-12
-9
-6
-3
3
6
9
12
Months from Index Date


Female by Deployment Status
Non-GWOT
GWOT
# of Encounters
30
25
20
15
10
5
0
-12
-9
-6
-3
3
6
9
12
Months from Index Date

CHAPTER 5

INTRODUCTION

Chapter 1 was an introduction in the which the investigator presented the background to the research question, the specific research purpose and research questions, and the research methodology used to investigate the topic. Chapter 2 was a manuscript prepared for submission to a peer-reviewed journal in which the investigator quantified 90-day health care utilization by active duty service members with a first diagnosis of mild traumatic brain injury, irrespective of premorbid or comorbid psychological health conditions. Chapter 3 was a manuscript prepared for submission to a peer-reviewed journal in which the investigator quantified health care utilization by active duty service members with a first diagnosis of mild traumatic brain injury, and investigated the effects of premorbid or comorbid PTSD on health care utilization prior to and following injury. Chapter 4 was a manuscript prepared for submission to a peer-reviewed journal in which the investigator quantified one-year health care utilization by active duty service members with a first diagnosis of mild traumatic brain injury, with a specific focus on the gender-related differences in the pattern of utilization of outpatient specialty clinics as well as total utilization. Chapter 5 provides a summary of the study, a summation of the results, and recommendations for future research.

SUMMARY OF THE STUDY

Overview of the Problem

Mild traumatic brain injury (mTBI) is a frequent cause of injury of active duty service members (SMs). Studies of veterans, with or without comorbid psychiatric disorders, report

increased health care utilization after an mTBI. Mild TBI and related psychological health problems have significant impacts on resource planning by the military health system, military operational readiness, and the quality of life of individual SMs. However, there are few studies of health care utilization by active duty SMs following an mTBI diagnosis, and the acute post-injury pattern of health care utilization is largely unknown. What is not known is: 1) the acute post-injury (90 day) pattern of health care utilization by active duty SMs with a first diagnosis of mTBI, 2) the effect of premorbid or comorbid PTSD on the pattern of health care utilization, and 3) the one-year pattern of health care utilization by this population of SMs. This study investigated the patterns of health care utilization in the 90-day and one-year pre- and post-injury periods by SMs with premorbid PTSD, with new onset PTSD, and SMs with no psychological health conditions.

Purpose statement

The purpose of this study was to quantify the pre-injury to post-injury change in health care utilization by active duty SMs with a first diagnosis of mTBI.

Methodology

This was a retrospective analysis of electronic health record data from 46,247 active duty service members with a first diagnosis of mTBI. Males comprised 87% of the sample and 26% of SMs had a deployment-related mTBI. Health care utilization 90 days and 365 days prior to and following mTBI diagnosis was analyzed using non-parametric statistics. Changes in health care utilization were compared by age, gender, whether a SM had a deployment-related injury, and by the presence or absence of PTSD prior to or following mTBI.

Major Findings

In the 90 days following a diagnosis of mTBI, mean utilization more than doubled from 6.3(±11.9) visits to 14.7(±26.1) visits. Median utilization increased from three to six visits (Z=-105, p<.001, r=.35), with 92% of SMs having at least one outpatient encounter. Males increased mean utilization from 6.1(±12) to 14.94(±27) visits, median utilization increased from three visits to six visits (z=-101, p<.001 r=.50). Females increased from an average of 7.8 visits pre-injury (±11.4) to of 12.93 (±18) visits post-injury, and median utilization increased from 4 visits pre-injury to seven visits post-injury (Z=-30, p <.001, r=.39). Service members with a war-related mTBI (GWOT) had the largest increase in utilization from a median of 4 (mean 8.43±26.4) visits pre-injury to a median of 13 (mean 26.4±37.7) visits post-injury (Z=-73.4, p<.001, r=.67).

Service members with pre-existing PTSD demonstrated far higher pre-injury health care utilization than SMs with mTBI_Only or new onset PTSD, with a mean of 20.4±21.7 visits pre-injury, increasing to 29.5(±29.5) visits post-mTBI. Median utilization increased from 14 visits pre-injury to 20 visits post-injury (Z=-23.08, p<.001, r=.25). Service members with pre-existing PTSD with a war-related injury demonstrated a moderate (r=.36) increase in median utilization, from 14 (mean 20.8±21.7) visits pre-injury to 25.5 (mean 35.0±31.5) visits post-injury (Z=-22.95, p<.001). Non-GWOT SMs with pre-existing PTSD also demonstrated a moderate (r=.33) increase in median utilization from 16 visits pre-injury to 24 median visits post-injury (Z=-7.78, p<.001)

Service members with new onset PTSD demonstrated substantial increases in utilization from the 90 days pre-injury to the 90 days post-injury, with a large (r=.55) increase from a pre-injury median of 3 (mean 5.5±11.4) visits, to a median of 17 (mean 32.1±41.6) visits post-injury (Z=-43.61, p<.001). The youngest SMs demonstrated the largest (r=.56) increase, from a

median of 2 (mean 5.3±13.5) visits pre-injury, to a median of 20 (mean 38.6±50.3) visits post-injury (Z=25.91, p<.001). SMs with a war-related injury and new onset PTSD demonstrated a large (r=.58) increase in median utilization, from a pre-injury median of 3 (mean 5.6±12.3) visits, to a median of 23 (mean 39±46.2) visits post-injury (Z=-35.09, p<.001).

Overall utilization from one-year pre-injury to one-year post-injury increased significantly by all SMs. Males utilized less median care in both the pre-injury and post-injury periods than females, with a moderate (r-.38) increase from 9 visits pre-injury to 19 visits post-injury (Z=-107.2, p<.001). Females had a small-to-moderate (r=.28) increase in utilization, from a median of 17 visits pre-injury to 26 visits post-injury (Z=-30.4, p<.001, r=.28). Mean utilization by males increased from 16.8(±26.5) visits pre-injury to 44(±71) visits post-injury and mean utilization by females increased from 26(±30) visits pre-injury to 43(±55) visits post-injury. Male SMs with a war-related mTBI had the largest increase in utilization from a median of 16 (mean 19.5±31.1) visits pre-injury to a median of 40 (mean 77.2±97.1) visits post-injury (Z=-78.1, p<.001, r=.52). Female GWOT SMs, too, had a large increase in utilization from a median of 16 (mean 24.5±28.7) visits pre-injury, to a median of 51 (mean 81±87) visits post-injury (Z=-17.3, p<.001, r=.50). Service members with a war-related mTBI had the highest post-injury utilization, with GWOT males demonstrating a median utilization of 12 visits (mean 26±38) in the three months immediately following diagnosis and a median of 9 visits (mean 19±26) in months 4-6 post-mTBI, before declining to a median of 6 visits (mean 15±23) by month 12. Similarly, GWOT females had a peak median utilization of 14 visits (mean 25±28) in the three months immediately following diagnosis and a median of 12 visits (mean 22±26) at month 6, before declining to a median of 8 visits (mean 17±23) by month 12.

DISCUSSION

Service members are generally healthy, and rarely seek high amounts of health care when not acutely ill or injured, as evidenced by the general low rate of health care utilization three months and 12 months prior to mTBI. Despite a low rate of individual utilization, service members take advantage of universal access to care, as 80% of SMs had one or more visits in the pre-injury period, 91% had at least one visit in the 90 day post-injury period, and 98% had at least one visit in the one-year post-injury period. Approximately 25% of SMs sought care in mental health outpatient clinics prior to injury, and 38% of SMs sought care in mental health clinics post-injury.

SMs with war-related traumatic brain injury utilized the highest levels of total outpatient care, and utilized significantly high levels of specialty care. At least a portion of this utilization may be attributable to serving in a war zone, as an increased risk of mental health disorders following deployment has been reported previously (Milliken et al., 2007; Seal et al., 2007). War-injured SMs have the largest increase in utilization of mental health and neurology clinics, lending further support to evidence from previous studies attributing persistent mTBI symptomatology, at least in part, to psychological factors for SMs injured during a combat deployment (Fear et al., 2009; Hoge et al., 2008; Killgore et al., 2006; Schwab et al., 2017; Stein et al., 2016; Wilk et al., 2012). Although reasons for utilization was not investigated in this study, the large increase in utilization in mental health and neurology clinics by war-injured versus non-war-injured veterans highlights a need for future investigation into long-term post-mTBI utilization patterns by active duty SMs, to investigate if these increases are sustained, and if there are differences in long-term recovery related to patterns of health care utilization.

Service members with PTSD demonstrate the highest rates of post-injury utilization, seeking an equivalent of one-year's encounters in the 90 days following injury (Taylor et al., 2014; Taylor et al., 2015; Taylor et al., 2012). Service members with pre-existing PTSD had the highest rate of pre-injury utilization, with a median of nearly five visits per month, indicating active engagement with MHS outpatient services. A moderate increase in utilization indicates that SMs with pre-existing PTSD seek additional care following mTBI, with the highest rates by SMs with pre-existing PTSD and a war-related mTBI. The high post-injury utilization extends to SMs with new onset PTSD, with large increases in utilization by SMs with new onset PTSD, particularly those SMs with new onset PTSD and a war-related mTBI. The high rate of utilization by SMs with mTBI and PTSD potentially has far-reaching effects in terms of cost to the MHS, military operational readiness, and personal cost to the individual SM.

Despite the overall low median utilization of outpatient specialty clinics, SMs with a war-related injury use substantially more care following mTBI, with median utilization by males at 40 visits and median utilization by females at 51 visits in the year post-injury. Additionally, SMs with a war-related injury utilize significantly more mental health clinics than non-GWOT SMs and sustain high median utilization through the entire post-injury period studied, with a median rate of utilization double the within-gender median rate for the first six months post-injury. Prior to diagnosis with mTBI, GWOT SMs of both genders had median utilization rates equal to the within-gender median. Psychological factors such as post-traumatic stress, depression, and substance use disorders likely contribute to the sustained high-rate of healthcare utilization, as reported in previous studies. (B. E. Cohen et al., 2010; Drag et al., 2013; Kehle-Forbes et al., 2016; Schwab et al., 2017) Additionally, GWOT SMs have an mTBI documented in the EHR as

occurring while deployed, and deployment and combat exposure are known to be strong associated with development of mental health disorders (Hoge et al., 2006; Hoge et al., 2008; Kang et al., 2003), lending further support for high utilization of mental health clinics by GWOT SMs, as is the high prevalence of the polytrauma clinical triad of pain, postconcussive symptoms, and PTSD in veterans of Iraq and Afghanistan (Lew et al., 2009) which may explain high concurrent utilization of rehabilitation clinics and mental health services by GWOT SMs in the study.

LIMITATIONS

Several limitations of this study should be considered. First, the researcher intentionally used a definition of mTBI consist with the VA / DoD guidelines for determination of injury severity, which limited inclusion to two ICD-9 codes. Previous studies have used a broader range of ICD-9 codes as a definition of mTBI, and the narrow definition of mTBI in the study limits generalizability to the larger mTBI population. Additionally, use of ICD-9 coding of mTBI has been shown to both overestimate and underestimate the prevalence of injury, lack specificity, and inaccurately diagnose individuals who did not have an mTBI or who had traumatic noncephalic injury in addition to an mTBI (Bazarian et al., 2006; Moss & Wade, 1996; Powell et al., 2008)

Another limitation inherent to the use of EHR records for research is missing data. Approximately 63% of the study sample had no documentation of deployment status at the time of injury. This large number of SMs with an unknown deployment status limits comparison of the rate of utilization by SMs with a known GWOT or non-GWOT injury. The study showed higher rates of outpatient clinic by SMs with a documented GWOT or non-GWOT code, but SMs with more frequent clinical encounters may have more complete documentation

of the initial injury, as additional evidence may be gathered through subsequent visits beyond initial diagnosis.

Utilization of health care by SMs was assumed to be voluntary and self-determined, but the DoD mandates screening evaluations prior to and following deployment, with a requirement for multiple post-deployment evaluations in many instances. Administrative requirements to evaluate injured SMs, and screen operationally deployed SMs, likely increases the mean and median utilization of health care in the sample. Additionally, evaluation of mTBI and screening of SMs pre-and post-deployment may serve as a catalyst for further health care utilization, as SMs are referred or directed to additional clinical evaluation.

Further, the researcher did not account for physical premorbidities and comorbidities known to be commonly associated with mTBI. The operational tempo of the wars in Iraq and Afghanistan resulted in multiple and / or lengthy deployments by individual SMs, and exposure to combat is associated with high rates of psychological health problems, and combat-related TBI that results in persistent postconcussive symptoms is likely to occur concurrently with PTSD and noncephalic pain.

Finally, the analysis did not account for lifetime history of mTBI. Mild TBI is known to be vastly under-reported in civilian populations, and individuals with mTBI that met the narrow definition of injury in this study, where loss of consciousness was limited to less than 30 minutes or did not occur, may be less inclined to seek care following injury than individuals with a more severe form of mTBI. The analysis likely did not include many SMs with a first mTBI who did not seek care, and thus had no documented injury, as well as individuals who had a TBI prior to military service.

RECOMMENDATIONS

Future studies are needed to address remaining gaps in our understanding of health care utilization by active duty SMs with a first diagnosis of mTBI. The difference in mean and median utilization by SMs is indicative of a subset of high utilizers of health care that needs additional analysis to characterize high utilizers of care and to differentiate reasons for use of health services. Future investigation into long-term post-mTBI utilization patterns by active duty SMs, to investigate how long the increase in utilization is sustained, and how long-term utilization differs by age, gender, and deployment status.

Additionally, the potential relationship between short-term utilization and long-term outcomes is poorly understood. Early intervention in psychological health conditions has shown to reduce symptomatology and improve outcomes, and the same may be true for SMs with an mTBI. Education of SMs in course of mTBI symptomatology has been reported to be an effective short-term treatment strategy, but it is unknown if education is an effective long-term treatment modality.

Finally, quantitative analysis is an efficient means to estimate the amount of health care utilization by an individual, but cannot conclusively determine an individual's reason for seeking care, which may be further derived through qualitative or a mixed-methods analysis. Reasons for utilization were not investigated in this study, and future work into post-mTBI health care utilization may reveal differences in patterns of health seeking behavior based upon motivation for care or self-reported symptomatology over time.